science & innovation

Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL RESEARCH UNIVERSITY

SOUTH AFRICA 2030
SCIENCE, TECHNOLOGY & INNOVATION FORESIGHT

Follow up data analysis to support the choice of priorities and quantify the possible effects of the priorities for the STI 2030 decadal plan

February 2021
Moscow

LIST OF ABBREVIATIONS

DPT vaccine – a class of combination vaccines against three infectious diseases in humans: diphtheria, pertussis (whooping cough), and tetanus

FAO – Food and Agriculture Organization of the United Nations

GDP – Gross domestic product

GNI – Gross national income

OECD – Organization for Economic Co-operation and Development

PPP – Purchasing power parity

UNICEF – United Nations Children's Fund

Foresight studies have been undertaken to investigate the future of science, technology and innovation (STI) and how these can serve for improving the quality of life of citizens, and for wealth creation, while achieving the goals of sustainable development. A national foresight exercise was undertaken to identify STI priorities and strategies towards 2030. The South African National STI Foresight (SAForSTI) 2030 study aimed contribute to the following STI objectives of the country:

- Advancing the capacity of the national system of innovation to contribute to sustainable socio-economic development.
- Enhancing South Africa's capacity for generating knowledge to produce high-quality research outputs, as well as innovative products and processes thereafter.
- Developing appropriate human capabilities in the STI sector to meet the needs of society.
- Building world-class infrastructure in the STI sector.
- Positioning South Africa as a strategic international research, development and innovation partner and destination.

Building on the national foresight exercise, SAForSTI 2030, the present study delves deeper in four selected areas, namely, (i) Health Innovation, (ii) Circular Economy and Climate Change, (iii) High-tech Industrialisation, and (iv) Education for the Future and the Future of Society. Each area is investigated by considering their impacts on 12 key indicators that are critical for South Africa's holistic development, namely, economic growth, job creation, high-quality healthcare services, high living standards, access and supply of clean water, affordable food, carbon emission reduction, low greenhouse gas emissions, export growth and competitiveness, skills development, renewable energy growth, and poverty alleviation.

A novel quantitative approach based on big data analytics was designed and used for this study, combining statistical, semantic, and scientometric data. Statistical data presented the socio-economic trends in South Africa in the last 20 years, while semantic data showed what is on the agenda for each of the selected areas, along with new and emerging opportunities and challenges to be considered. Finally, the scientometric analysis indicated the country's research and scientific capacity to address those challenges and to innovate for the future. The data analytics part was enriched with the critical viewpoints of South African experts.

The results of the study show that South Africa has made some progress in the past decades in socio-economic and environmental development, with better healthcare services for citizens, progress towards using cleaner and renewable energy sources, implementing technologies towards Industry 4.0, and providing access to education and better employment opportunities for the population. However, to achieve the vision of sustainable economic, environmental and social development, there are still more steps to be taken.

Among the areas focused on, health innovation emerges as a key priority for socio-economic development. The first and foremost concern for health innovation is reducing the burden of HIV/AIDS, Tuberculosis (TB), and more recently COVID-19 and other pandemics. South Africa needs to overhaul its health system. New service delivery systems should be developed utilising e-health technologies and applications. The population's access to affordable and high-quality healthcare services, generic drugs, and vaccination should be provided by the end of the next decade. The ultimate aim is to create a healthy population that leads a healthy lifestyle, places a minimal burden on the healthcare system, and makes a maximal contribution to socio-economic life.

For the transition to a circular economy and cleaner environment, first of all, clean energy solutions should be developed. South Africa's energy mix should be enriched through the exploitation of new and renewable energy sources, along with greater efficiency in reducing resource use, waste and emission generation. The agriculture sector and agro-processing should be developed with minimum loss of agricultural products. A shift to electric transport is needed. Alternative building materials such as low-carbon steel and cement should be developed and used while providing the necessary insulation for minimum energy loss. The long-term goal is to achieve zero waste in manufacturing and the economy overall.

High-tech industrialisation should cover not only large enterprises but also small, medium and micro enterprises by equipping them with the necessary skills and infrastructure to be ready for the next industrial revolution. The industrial Internet of things (IIoT), digital manufacturing, and the implementation of artificial intelligence and machine learning technologies emerge as priority areas to be considered. An economic system should be developed to adopt digital financial technologies. Meanwhile, emerging cybersecurity issues need to be addressed.

Finally, it is essential to educate society to be ready for the next "digital decade". Hence, in the area of Education for the Future, society should be able to access the Internet at a low cost. Online education systems should be developed and made widespread. New curricula should be

developed that align with digitalisation and industrialisation trends, as well as the need to prepare for the transition to a circular economy. In the medium term, artificial intelligence and virtual reality technologies should be deployed. All of these strategic steps should lead to the development of a globally competitive workforce by 2030.

With all its findings and recommendations, this report is relevant and important for a wide variety of audiences. First of all, policymakers and practitioners in a wide variety of policy domains, from science and technology to health, education, economy and industry, will greatly benefit from this study for articulating their future visions, setting priorities, and developing strategies and action plans. Research areas identified will be a guide to researchers at universities and other public and private research institutions. Students engaged in public policy, corporate strategy, and STI studies will find this study a valuable source of information for planning their future academic and professional careers. Finally, foresight researchers and practitioners will benefit from this study, with its novel methodological combination of qualitative and quantitative approaches for formulating forward-looking, evidence-based, and inclusive policies and strategies.

BACKGROUND AND OBJECTIVES

The process of developing the new STI decadal plan includes the identification of priorities with clearly defined targets that must be specific, measurable, actionable, realistic, relevant and time bound. To achieve this objective, it is necessary to deepen the analysis of the possible socio-economic impacts of the earlier identified nine priority domains and use the analysis to inform the choice of priorities and missions. The choice of priorities is important not just because of current global COVID-19 crisis and limited resources but given South African triple challenge of poverty, employment, and inequality as well as inadequate investment in STI.

To fulfil the objectives, the proposed study intends to deepen an analysis and understanding of the potential socio-economic impact of STI 'priorities' and use the results of such analyses to provide further input in the new decadal plan for STI. As part of the decadal plan development process, four areas have been selected for developing possible missions/ priorities, including:

- Circular economy/climate change.
- Health innovation.
- Education for the future and the future of society.
- High-tech industrialisation.

These have been selected since they are among the cross-cutting application areas across sectors and role players in government and the broader National System of Innovation. The measures of impact of the possible choice of missions/priorities must be uniformly applicable and adhere to standard definitions commonly used in South Africa. In determining the socioeconomic impact of the selected STI priorities, several possible indicators/priorities are proposed. These are:

- Economic growth
- Job creation
- High quality health care services
- High living standard
- Access and supply of clean water
- Affordable food
- Carbon emission reduction
- Low greenhouse gas emission
- Export growth and competitiveness
- Skills development

- Renewable energy growth
- Poverty alleviation

The results of the proposed study includes a set of actionable priority areas with quantifiable targets as well as possible actions to be undertaken to achieve set targets. The process of achieving targets will be presented on a timeline with actions across short-, medium- and long-term to enable effective implementation.

The proposed process combines quantitative methods of Big-Data, semantic, statistical and scientometric analyses with qualitative methods of workshops and expert consultations. The four areas are investigated in detail with three types of complementary analysis:

1. Statistical analysis giving a background to the study to understand South Africa's trends and present position using the aforementioned key indicators
2. Semantic analysis makes use of the newest semantic algorithms and models (multi-layered neural embeddings) to set a policy agenda for South Africa through semantic maps, trend maps and other analytical tools of the intelligent Foresight Analytics system (iFORA) as a big data-based intelligence system
3. Scientomeric analysis aims at providing a scientific profile of South Africa to demonstrate how attainable strategic targets interms of science, technology and innovation potentials

This process has also ben complemented with joint workshops for high-level interpretation of the results with clearly defined targets that must be specific, measurable, actionable, realistic, relevant, and time-bound for scientifically grounded socio-economic policy recommendations for addressing the challenges of South Africa. Two workshops were organized as part of this study. The first workshop aimed at identifying and clarifying the areas to be investigated through the interpretation of the results generated from the data analytics phase. The workshop was be performed in consultation with the South African experts to formulate a definition of fields and areas to be covered within the scope of the analysis to be performed. The second workshop helped to identify priorities, policy recommendations and a strategic roadmap for South Africa towards 2030 with necessary targets in the long, medium and short term.

The report is structured as follows. The first section provides the results of the statistical analysis by using a wide variety of globally recognized databases to examine the the state of development in the priority areas for South Africa in the last 20 years. South Africa's position is

also benchmarked with other similar countries in the world and with different groups of countries, such as OECD, Sub-Saharan Africa and the World. This gives a better picture on where South Africa is positioned globally and regionally. The second section provides the results of the Semanic Analysis, which provides the key topics under each of the four areas, makes an assessment in relation to the indictaors and priority areas identified, and maps trends in each domain with their clusters formed by the significant topics. The third section provides the results of the Scientometric analysis, which shows South Africa's science, technology and innovation potentials of the country by making assessment of the country's scientific publications in the last 20 years. Finally, the fourth section provides feedback from the South African experts through the workshops organized, additional analysis performed, and policy recommendations for South Africa towards 2030. A strategic roadmap is provided to show the strategic actions to be undertaken within the next decade.

Acknowledgements

The core team members of ISSEK HSE involved in this study are: Prof. Ozcan Saritas and Prof. Alexander Sokolov, Mr. Ilya Kuzminov, Ms. Polina Lobanova, Mr. Alexander Belikov, and Mr. Maxim Kotsemir along with the other members of the iFORA team. We are grateful to the Director-General Dr. Phil Mjwara of the Department of Science and Innovation (DSI) and Dr. Mlungisi Cele of National Advisory Council of Innovation (NACI), DSI for their encouragement to undertake this study, and for their help and support during the process. We greatly appreciate the valuable contributions of the South African experts, who dedicated their valuable time and effort to participate the two workshops organized. Their input was instrumental for formulating the strategies and policy recommendations as a result of this study.

1 STATISTICAL ANALYSIS

The statistical analysis includes international statistical indicators that characterize the following factors of socio-economic development:

- Economic growth,
- Job creation,
- High quality health care services,
- Access and supply of clean water,
- Affordable food,
- Carbon emission reduction,
- Low greenhouse gas emission,
- Export growth and competitiveness,
- Skills development,
- Renewable energy growth,
- Poverty alleviation.

For each of the analyzed factors of socio-economic development, an index was calculated that characterizes the level of development of the countries of the world in the corresponding area. The index for each of the factors was calculated as the arithmetic mean of all the indicators included in it.

To ensure the proportionality of the values used (the indicators used in the analysis have different dimensions, for example, percentages, units, people), normalization was performed using the formula:

$$N_q = \frac{(n_q - n_{min})}{(n_{max} - n_{min})}$$

where:

N_q – the normalized value of the indicator **n** for the country numbered **q**.

q – the ordinal number of the country (from 1 to 217).

n_q – the value of the indicator **n** for the country numbered **q**.

n_{max} – maximum value of indicator **n** for the entire sample of countries.

n_{min} – minimum value of indicator **n** for the entire sample of countries.

The theoretically possible maximum normalized value of the indicator is N_q =1, and the minimum value is N_q =0.

For indicators, whose higher value is interpreted negatively, the numerator of the fraction will have the form: ($n_{max} - n_q$). This makes it possible to calculate the average values for indicators whose larger and smaller values are interpreted differently.

The benchmark countries for comparison with South Africa are classified by the World Bank in the upper middle-income group. From this list, five countries with a large territory and a high population were selected (Brazil, Kazakhstan, Mexico, Turkey, Ecuador), which makes them comparable in basic parameters with South Africa. In addition, the average values for the world, OECD member countries, as well as countries located in sub-Saharan Africa are given for comparison.

The statistical analysis was carried out based on quantitative data obtained from many open international comparable databases. The main data source was the World Bank's World Development Indicators database. In addition to this source, data from the OECD National Accounts data files and International Monetary Fund databases were used for the analysis of economic development. The healthcare sector analysis involved data from the World Health Organization and the United Nations Children's Fund. Data from the Food and Agriculture Organization of the United Nations was used as a source of information for several indicators of the availability of food and clean water services.

1.1 Economic growth

1.1.1 GDP per capita, PPP (constant 2017 international $)

GDP per capita based on purchasing power parity (PPP). PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. GDP at purchaser's prices is the sum of gross value added by all resident producers in the country plus any product taxes and minus any subsidies not included in the value of the products. It is calculated

without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are given in constant 2017 international dollars.

South African GDP per capita data (Figure 1.1) shows that in the poast couple of decades the country has remained within the range of 10K to 12.5K USD range. This indicates a middle-income trapped country. This is one of the challenges for the further development of the country in the next decade. Necessary industrial, technological, and economic measures should be taken for a prosperous society by 2030. Among the other benchmark countries, South Africa is positioned after Brazil in GDP per capita with 12,482 USD, which is below the world average of 16,944 USD (Figure 1.2).

Source: International Comparison Program, World Bank | World Development Indicators database, World Bank | Eurostat-OECD PPP Programme.

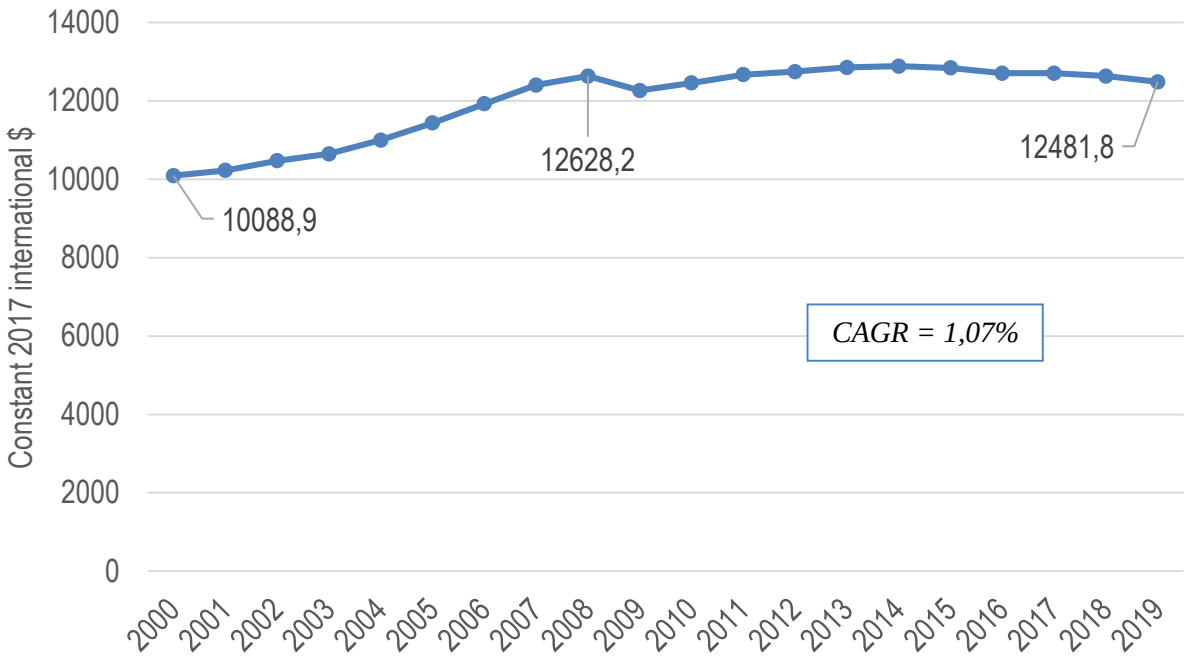

Figure 1.1. GDP per capita of South Africa (PPP)

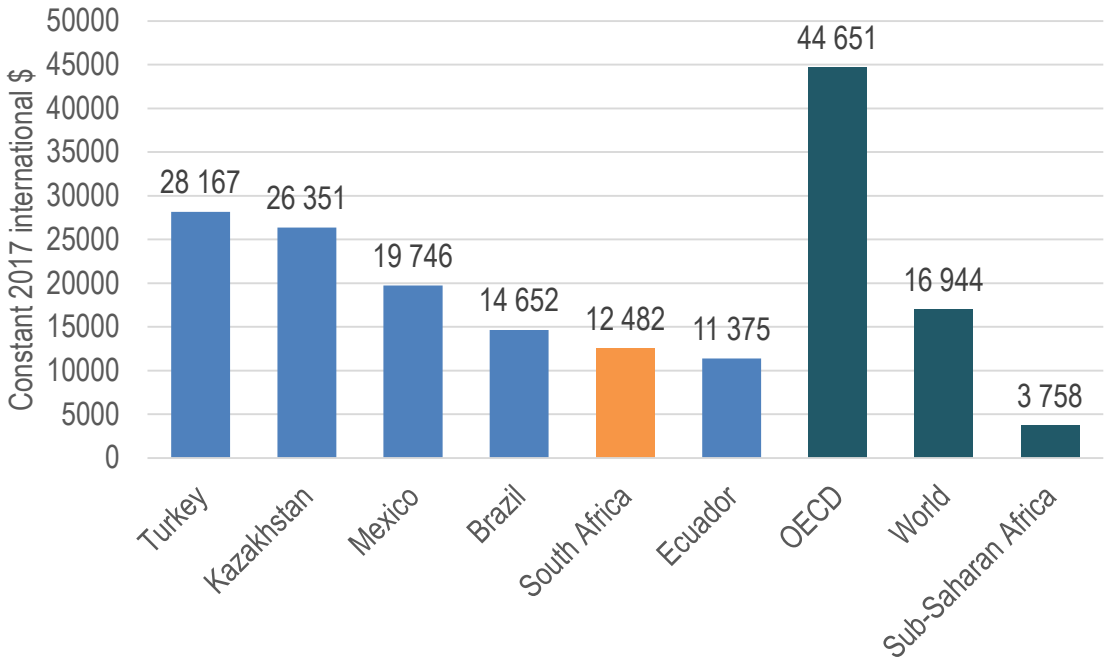

Figure 1.2. GDP per capita, 2019 (PPP)

1.1.2 GDP growth (annual %)

Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

In line with the GDP PPP figures, the GDP growth rate data supports the profile of a middle-income trapped character of the South African economy with very low and sometimes negative growth rates like in 2009. These growth rates are comparable to Ecuador and Mexico among the benchmark countries (Figure 1.3 & 1.4).

Source: World Bank national accounts data, and OECD National Accounts data files.

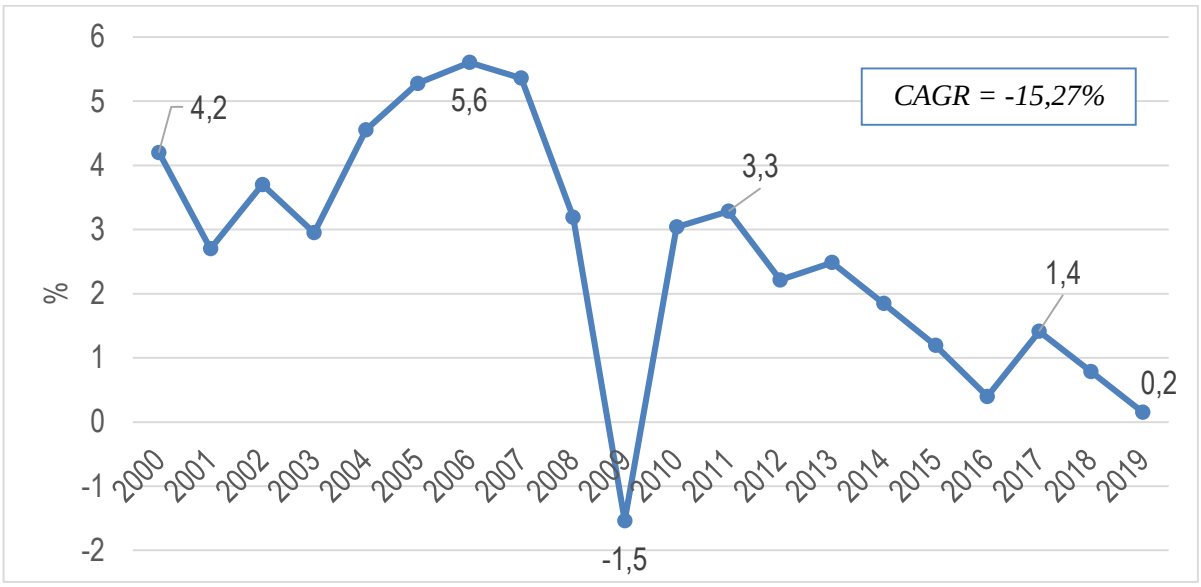

Figure 1.3 GDP growth rate of South Africa

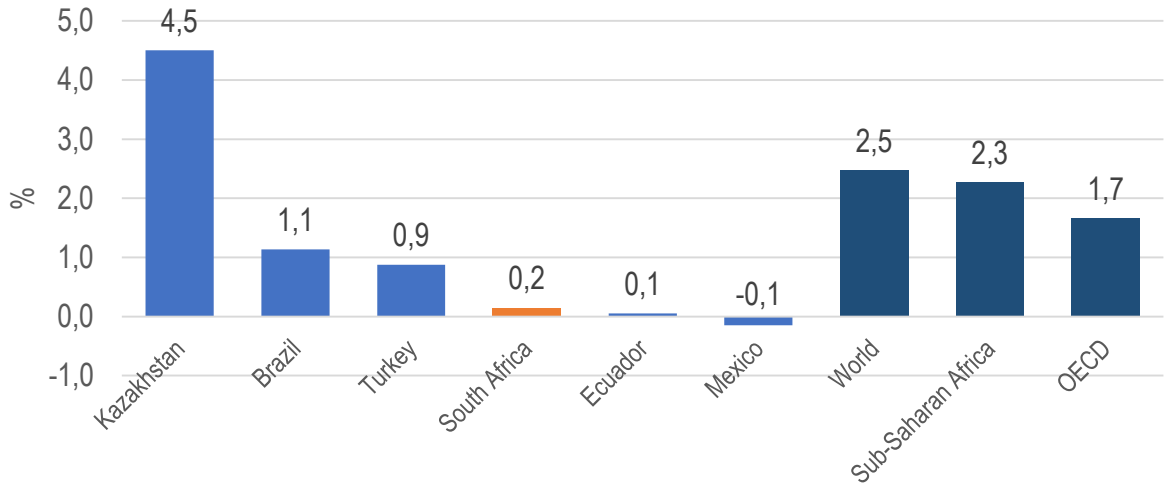

Figure 1.4 GDP growth rate, 2019

1.1.3 External debt stocks (% of GNI)

Total external debt is debt owed to nonresidents repayable in currency, goods, or services. It is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Short-term debt includes all debt having an original maturity of one year or less and interest in arrears on long-term debt. GNI (formerly GNP) is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad.

Data on external debt are gathered through the World Bank's Debtor Reporting System (DRS). Long term debt data are compiled using the countries report on public and publicly guaranteed borrowing on a loan-by-loan basis and private non-guaranteed borrowing on an aggregate basis. These data are supplemented by information from major multilateral banks and official lending agencies in major creditor countries. Short-term debt data are gathered from the Quarterly External Debt Statistics (QEDS) database, jointly developed by the World Bank and the IMF and from creditors through the reporting systems of the Bank for International Settlements. Debt data are reported in the currency of repayment and compiled and published in U.S. dollars. End-of-period exchange rates are used for the compilation of stock figures (amount of debt outstanding), and projected debt service and annual average exchange rates are used for the flows. Exchange rates are taken from the IMF's International Financial Statistics. Debt repayable in multiple currencies, goods, or services and debt with a provision for maintenance of the value of the currency of repayment are shown at book value. External debt stocks of South Africa have been constantly increase since 2005 reaching to 55.1 per cent in 2019. This is comparable to Turkey and Ecuador among the benchmark countries (Figure 1.5 & 1.6).

Source: World Bank, International Debt Statistics.

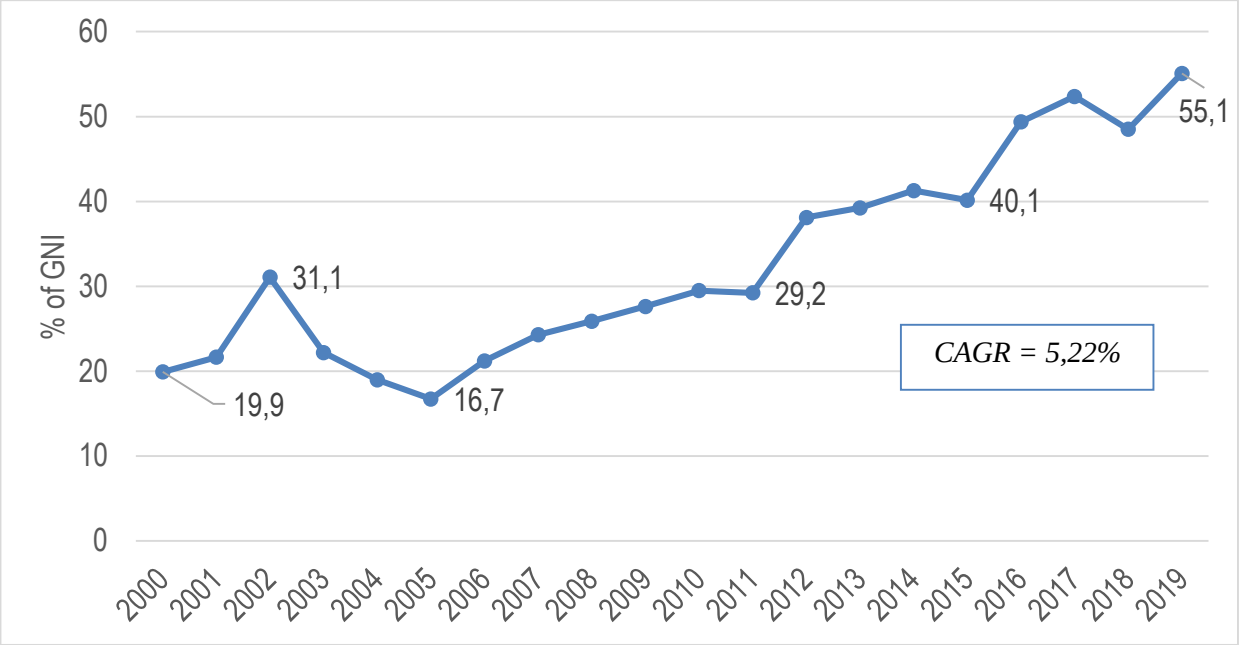

Figure 1.5 External debt stocks of South Africa

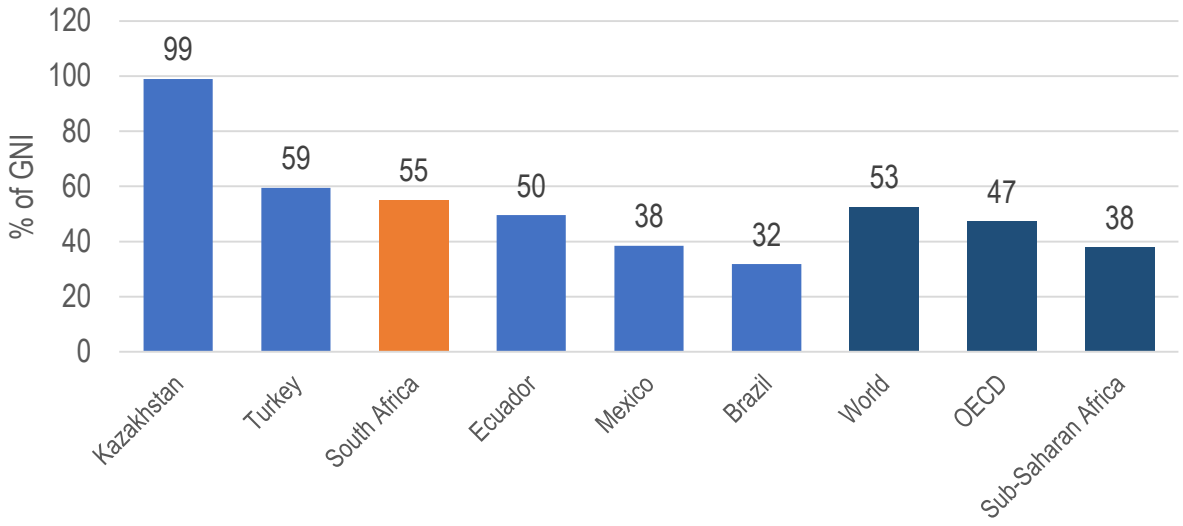

Figure 1.6 External debt stocks, 2019

1.1.4 Foreign direct investment, net inflows (% of GDP)

Foreign direct investment (FDI) are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP.

Data on equity flows are based on balance of payments data reported by the International Monetary Fund (IMF). FDI data are supplemented by the World Bank staff estimates using data from the United Nations Conference on Trade and Development (UNCTAD) and official national sources.

The internationally accepted definition of FDI (from the sixth edition of the IMF's Balance of Payments Manual [2009]), includes the following components: equity investment, including investment associated with equity that gives rise to control or influence; investment in indirectly influenced or controlled enterprises; investment in fellow enterprises; debt (except selected debt); and reverse investment. The Framework for Direct Investment Relationships provides criteria for determining whether cross-border ownership results in a direct investment relationship, based on control and influence. Distinguished from other kinds of international investment, FDI is made to establish a lasting interest in or effective management control over an enterprise in another country. A lasting interest in an investment enterprise typically involves establishing warehouses,

manufacturing facilities, and other permanent or long-term organizations abroad. Direct investments may take the form of greenfield investment, where the investor starts a new venture in a foreign country by constructing new operational facilities; joint venture, where the investor enters into a partnership agreement with a company abroad to establish a new enterprise; or merger and acquisition, where the investor acquires an existing enterprise abroad. The IMF suggests that investments should account for at least 10 percent of voting stock to be counted as FDI. In practice many countries set a higher threshold. Many countries fail to report reinvested earnings, and the definition of long-term loans differs among countries. BoP refers to Balance of Payments.

FDI is an important indicator for showing trust of external investors to a country's economy. FDI received by South Africa in the first decades of the 21st century remained low as percentage of the country's GDP, which compares to Turkey among the benchmark countries (Figure 1.7 & 1.8). FDI figures should be increased for a prosperous economy in the next decade.

Source: International Monetary Fund, International Financial Statistics and Balance of Payments databases, World Bank, International Debt Statistics, and World Bank and OECD GDP estimates.

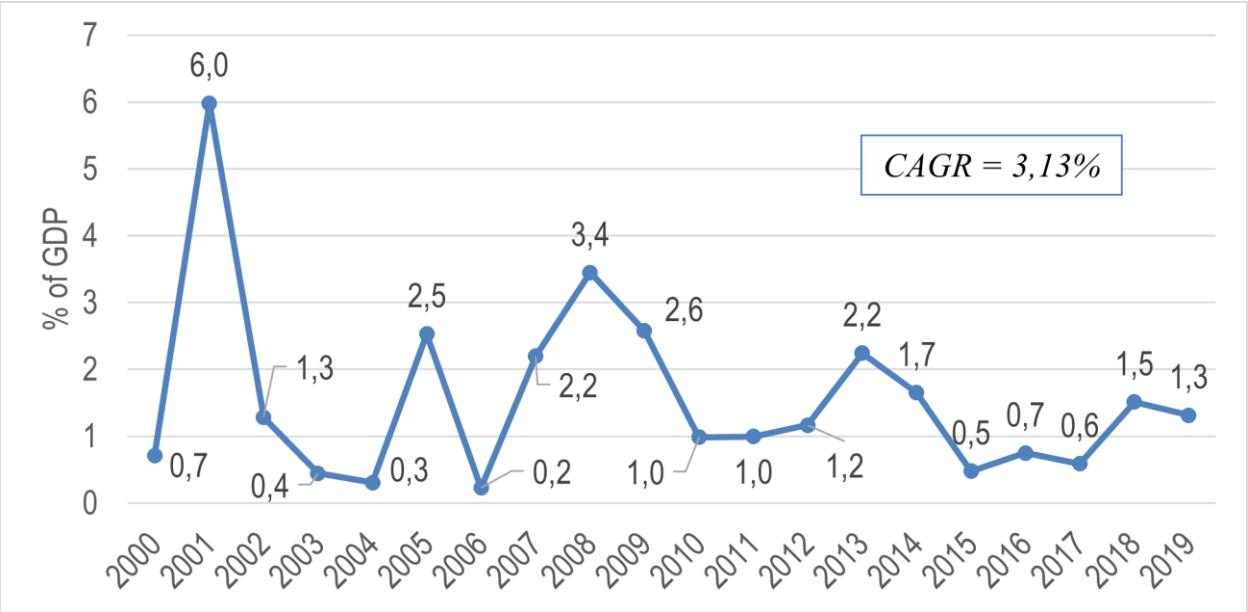

Figure 1.7. Foreign direct investment in South Africa

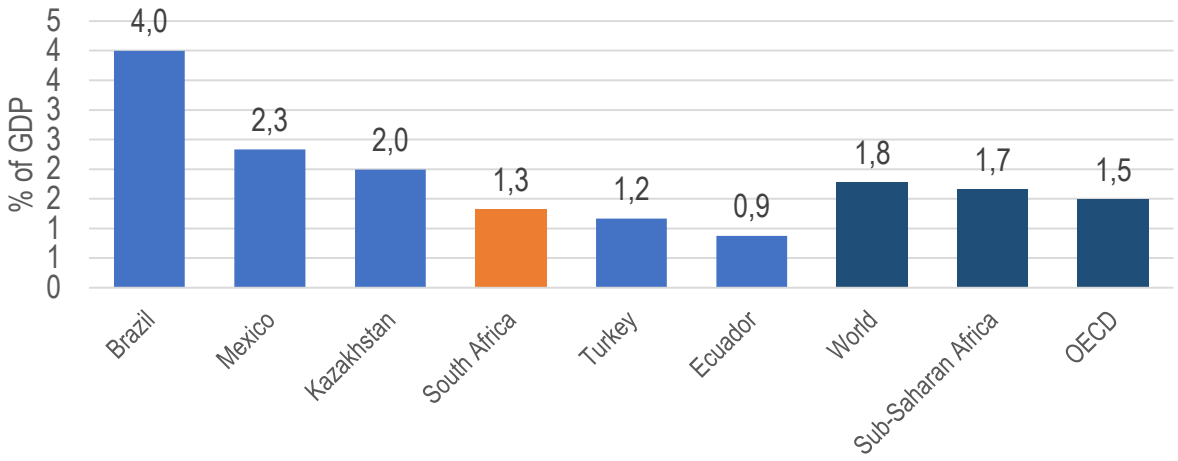

Figure 1.8. Foreign direct investment, 2019

1.1.5 Gross domestic savings (% of GDP)

Gross domestic savings are calculated as GDP less final consumption expenditure (total consumption). In other words, Gross Domestic Saving is GDP minus final consumption expenditure. It is expressed as a percentage of GDP. South Africa's GDS figures have been fluctuating between 18.5 and 21.3 per cent in recent years, with 18.5 per cent in 2019, which is below OECD and the World averages (Figure 1.9 & Figure 1.10).

Source: World Bank national accounts data, and OECD National Accounts data files.

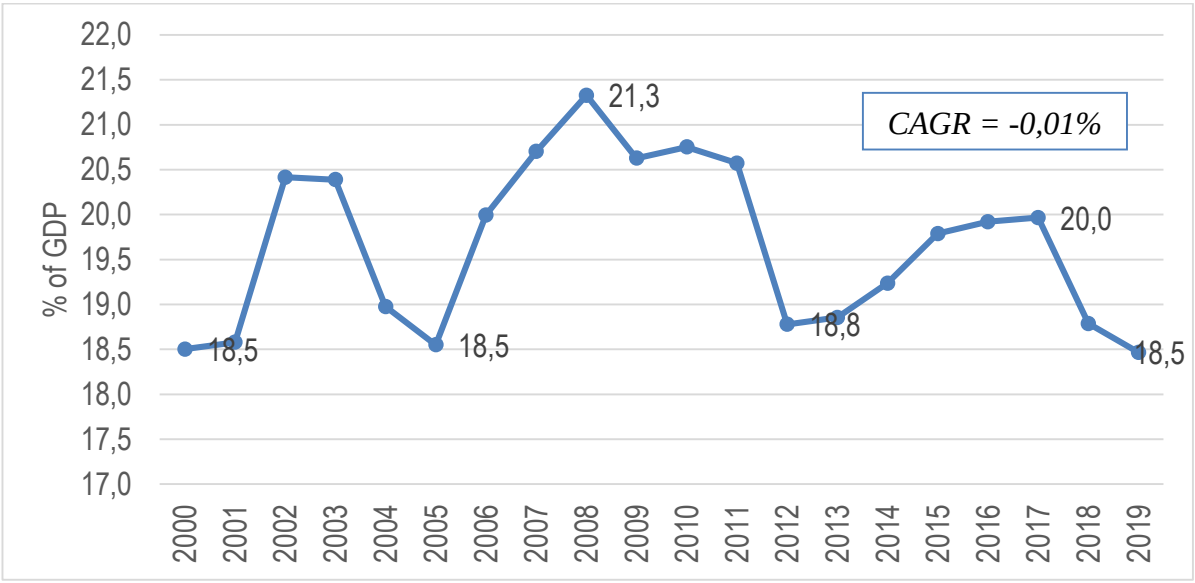

Figure 1.9. Gross domestic savings of South Africa

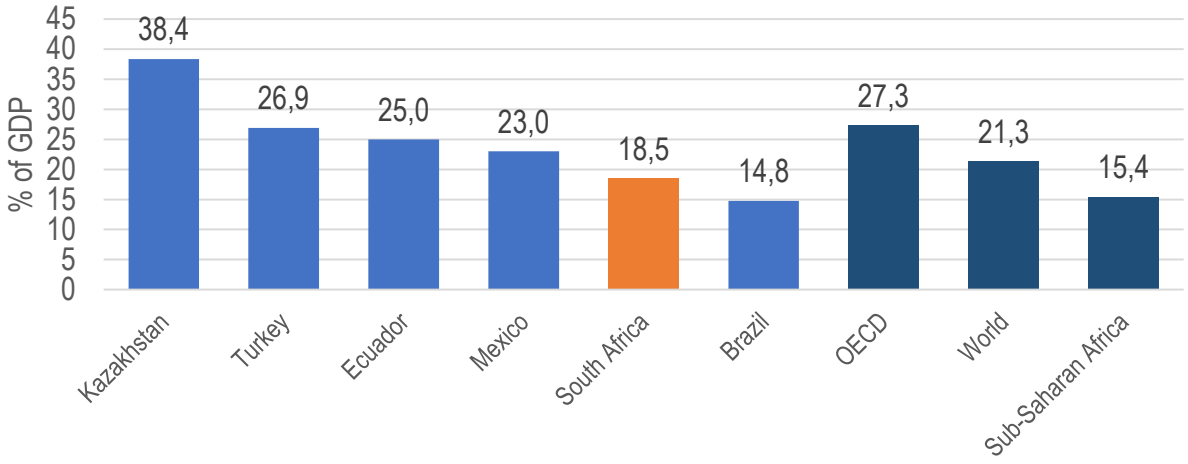

Figure 1.10. Gross domestic savings, 2019

1.1.6 Inflation, consumer prices (annual %)

Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used. Although annual inflation figures in South Africa have been high and fluctuating sharply, the last decade shows a relative stability with a figure of 4.1% in 2019. This figure is above the OECD, the World and Sub-Saharan averages, but is comparable to other benchmark countries except Turkey, which suffers from high inflation rates (Figure 1.11 & 1.12).

Source: International Monetary Fund, International Financial Statistics, and data files.

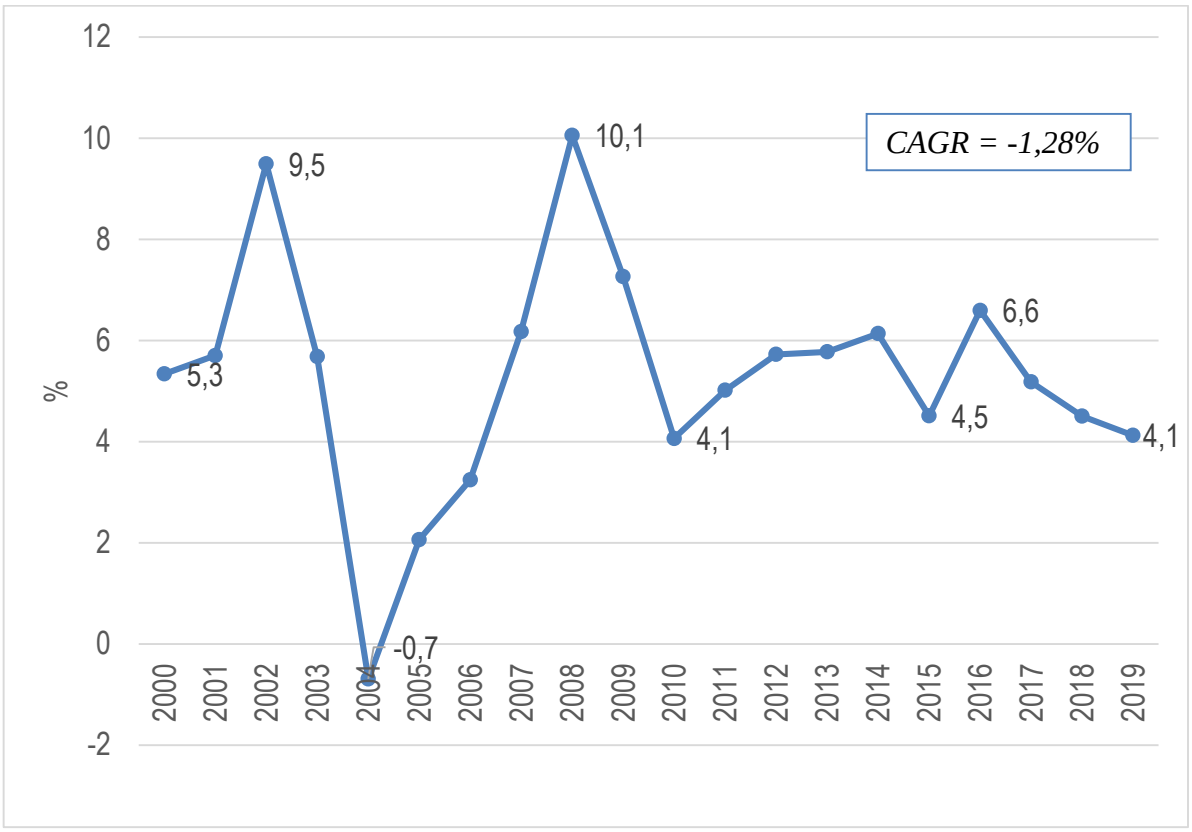

Figure 1.11. Inflation (consumer prices) of South Africa

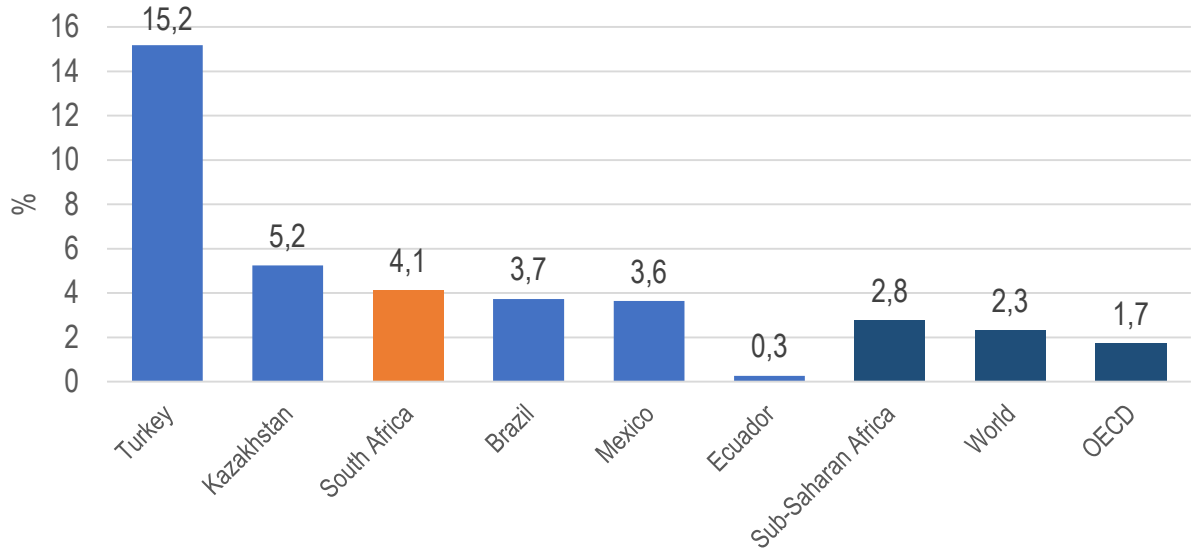

Figure 1.12. Inflation (consumer prices), 2019

1.1.7 Normalized indicators values and a composite index for the «Economic growth» factor

Figure 1.17 provides a combined assessment of all economic indicators above and synthesises them to constitute an "economic growth index", which shows South Africa's position among the benchmark countries. According to the figure South Africa has an average position in economic growth. This shows some progress, however more needs to be done of the country aims to reach its 2030 socio-economic development targets.

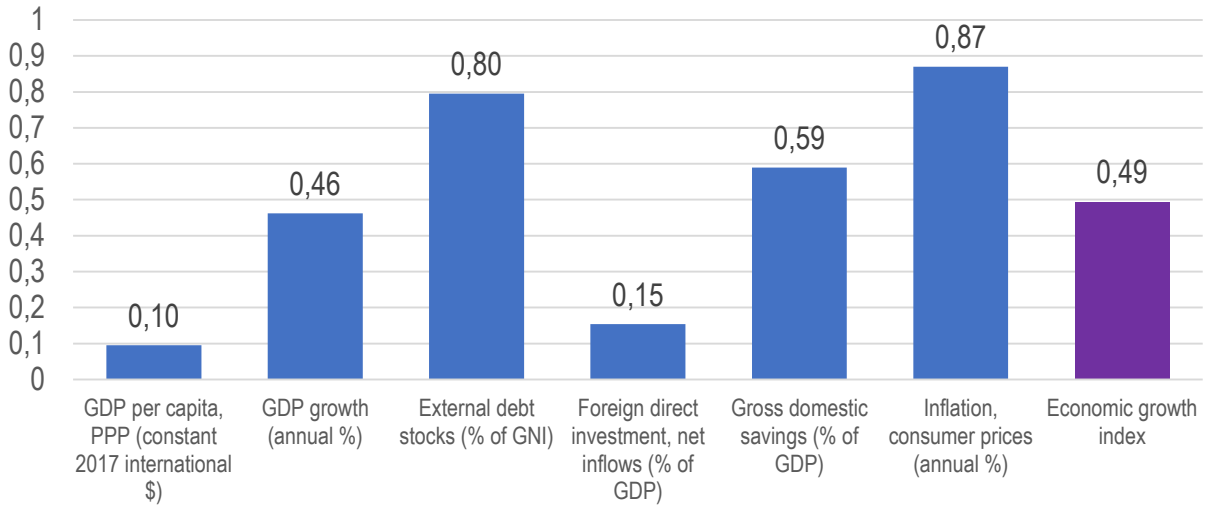

Figure 1.13. Normalized indicators values and a composite index for the «Economic growth» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.2 Poverty alleviation

1.2.1 Gini index (World Bank estimate)

Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Lorenz curve plots the cumulative percentages of total income received against the cumulative number of recipients, starting with the poorest individual or household. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. Thus, a Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.

South Africa has experienced a better performance in the equality of distribution in the early years of 2000s. However, since 2005 the figures have evolved towards inequality with GINI

index climbing to 63 per cent (Figure 1.14). This is the highest among the benchmark countries and higher than the world average of 36.6 percent (Figure 1.15).

Source: World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments. For more information and methodology, please see PovcalNet (http://iresearch.worldbank.org/PovcalNet/index.htm).

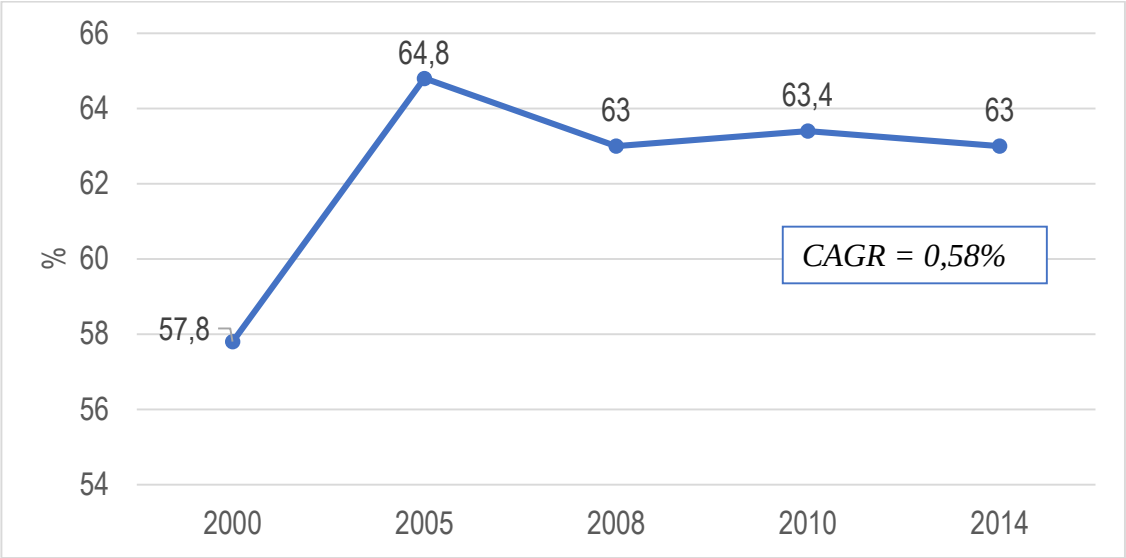

Figure 1.14. Gini index (World Bank estimate) of South Africa

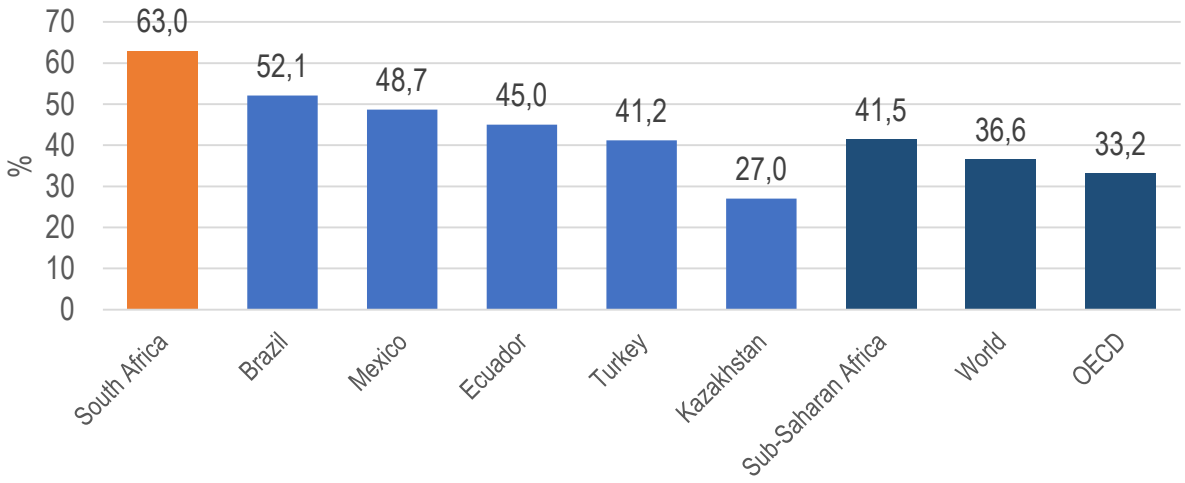

Figure 1.15. Gini index (World Bank estimate), 2014

1.2.2 Income share held by highest 10%

Percentage share of income or consumption is the share that accrues to subgroups of population indicated by deciles.

Inequality in the distribution of income is reflected in the share of income or consumption accruing to a portion of the population ranked by income or consumption levels. The portions ranked lowest by personal income receive the smallest shares of total income.

Data on the distribution of income or consumption come from nationally representative household surveys. Where the original data from the household survey were available, they have been used to directly calculate the income or consumption shares by quintile. Otherwise, shares have been estimated from the best available grouped data.

The distribution data have been adjusted for household size, providing a more consistent measure of per capita income or consumption. No adjustment has been made for spatial differences in cost of living within countries, because the data needed for such calculations are generally unavailable. For further details on the estimation method for low- and middle-income economies, see Ravallion and Chen (1996).

Currently the share of income held by the richest 10 per cent of South Africa is over 50 per cent. The rest of the 50 per cent is distributed among the remaining 90 per cent of the population (Figure 1.16). In terms of income inequality, South Africa has the most unfavourable figures among the benchmark countries (Figure 1.17).

Source: World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments. Data for high-income economies are from the Luxembourg Income Study database. For more information and methodology, please see PovcalNet (http://iresearch.worldbank.org/PovcalNet/index.htm).

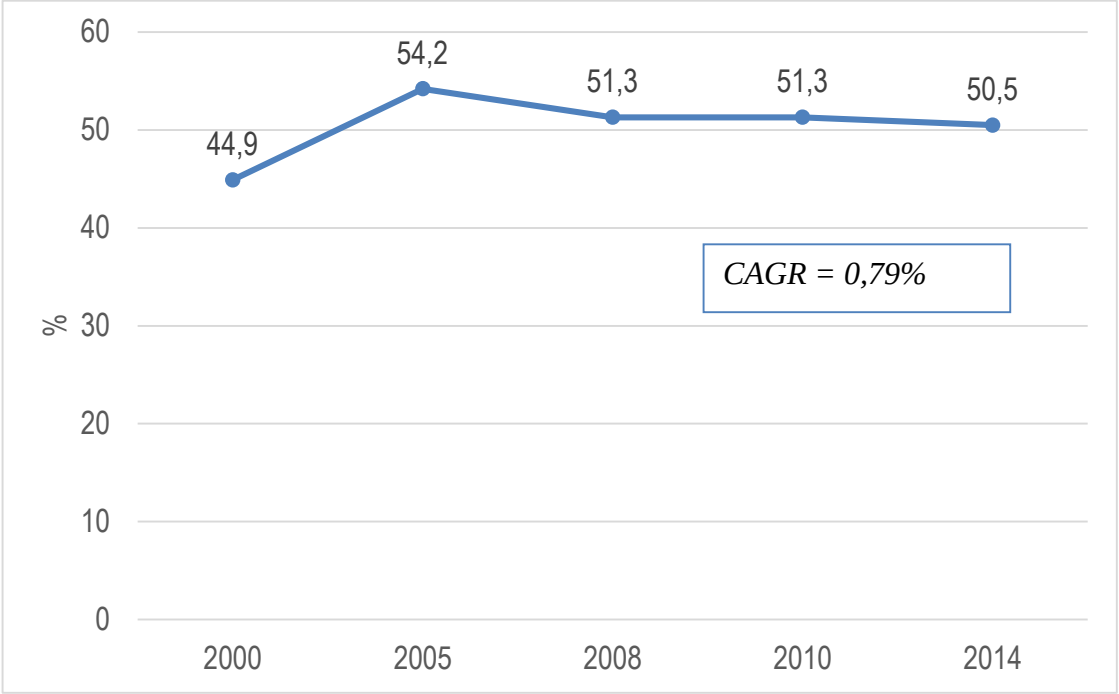

Figure 1.16. Income share held by highest 10% of South Africa

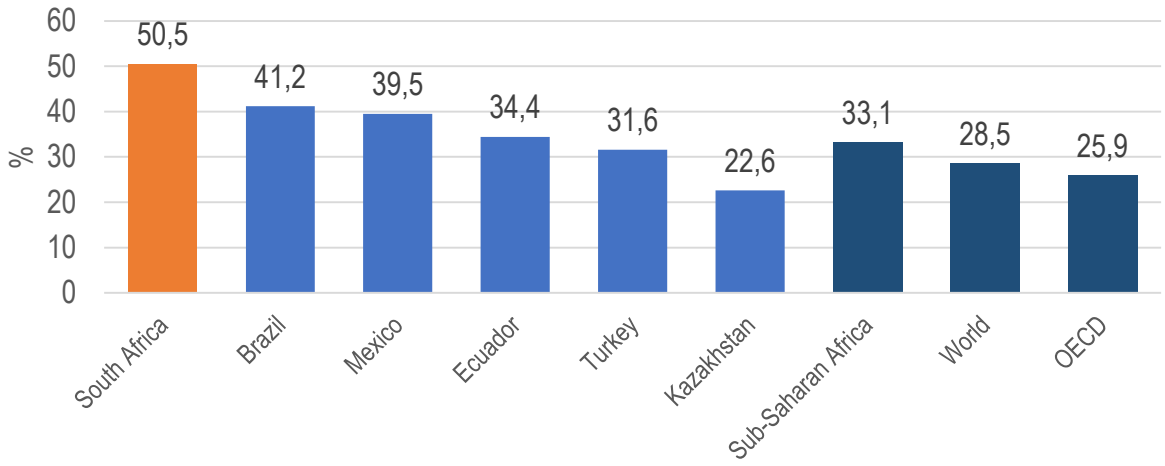

Figure 1.17. Income share held by highest 10%, 2014

1.2.3 Population living in slums (% of urban population)

Population living in slums is the proportion of the urban population living in slum households. A slum household is defined as a group of individuals living under the same roof lacking one or more of the following conditions: access to improved water, access to improved sanitation, sufficient living area, housing durability, and security of tenure, as adopted in the Millennium Development Goal Target 7.D. The successor, the Sustainable Development Goal

11.1.1, considers inadequate housing (housing affordability) to complement the above definition of slums/informal settlements.

South Africa experienced a steady decline in the number of people living in urban slums until 2010. However, since then just above a quarter of the urban population is living in slums (Figure 1.18). This is well below the other Sub-Saharan Africa, however the highest among the benchmark countries (Figure 1.19).

Source: United Nations Human Settlements Programme (UN-HABITAT)

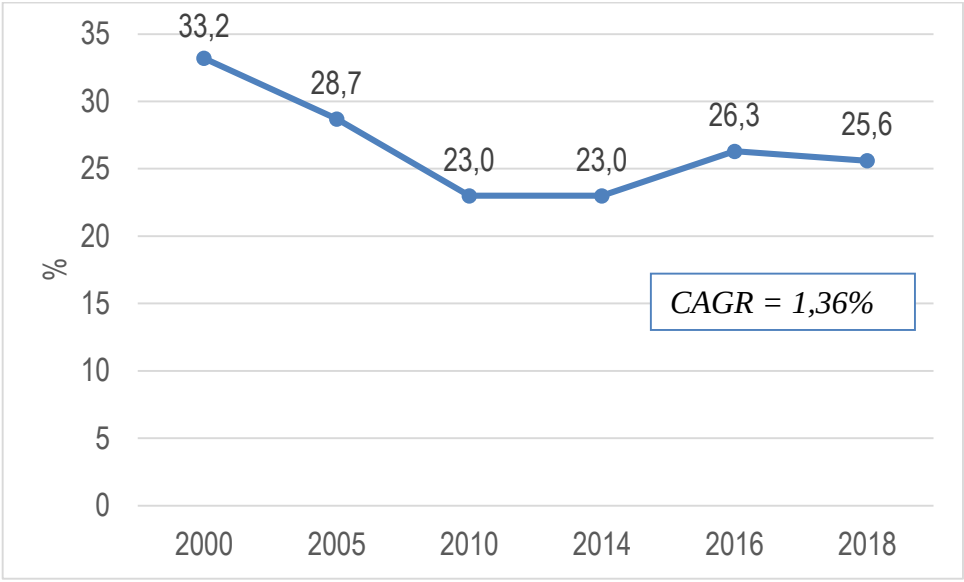

Figure 1.18. Urban population of South Africa living in slums

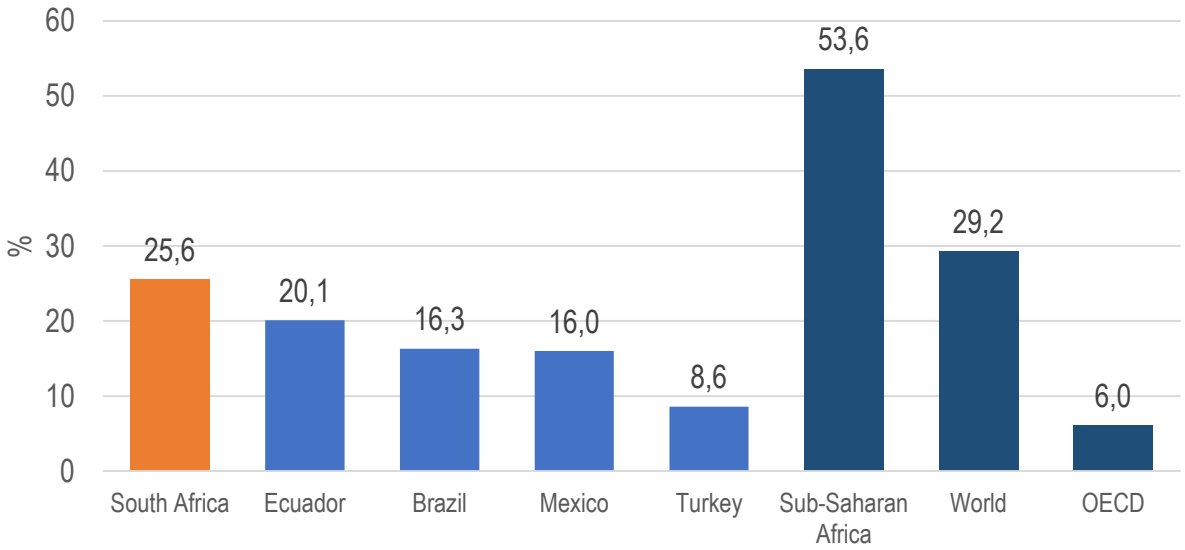

Figure 1.19. Urban population living in slums, 2018

1.2.4 Proportion of people living below 50 percent of median income (%)

The percentage of people in the population who live in households whose per capita income or consumption is below half of the median income or consumption per capita. The median is measured at 2011 Purchasing Power Parity (PPP) using PovcalNet (http://iresearch.worldbank.org/PovcalNet). For some countries, medians are not reported due to grouped and/or confidential data. The reference year is the year in which the underlying household survey data was collected. In cases for which the data collection period bridged two calendar years, the first year in which data were collected is reported.

In parallel to the other poverty indicators, the proportion of people living below 50 per cent of median income in South Africa is around 23.5 in the past decade. This is the highest among the benchmark counties and higher than the world average (Figure 1.20 & 1.21).

Source: World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments. Data for high-income economies are from EU-SILC or the Luxembourg Income Study database. For more information and methodology, please see PovcalNet (iresearch.worldbank.org/PovcalNet/index.htm).

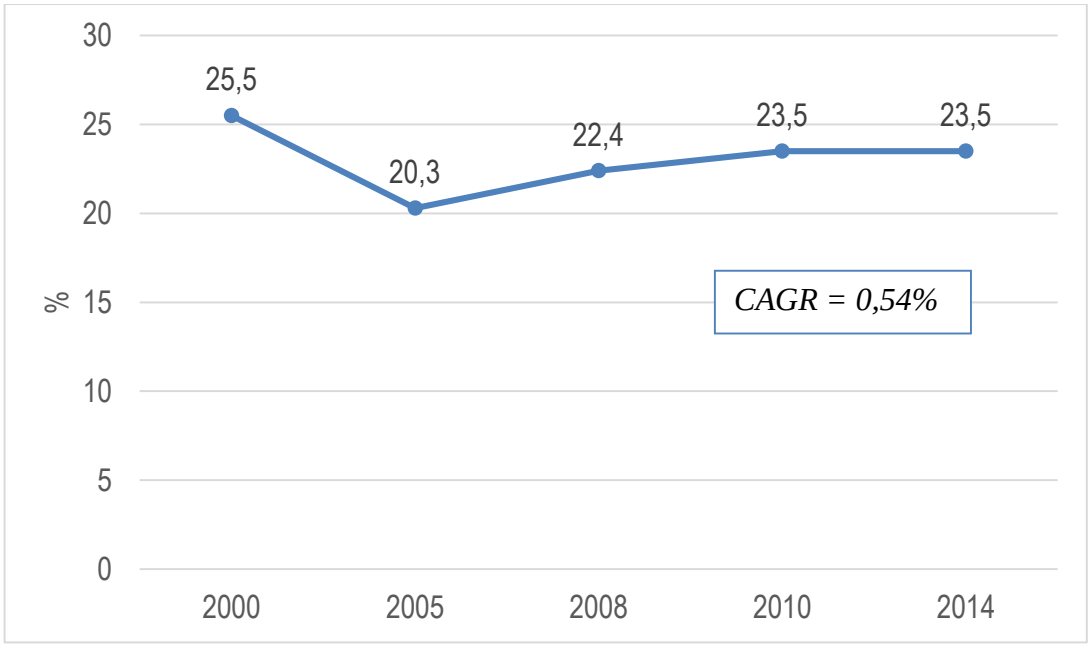

Figure 1.20. Proportion of people living below 50 per cent of median income

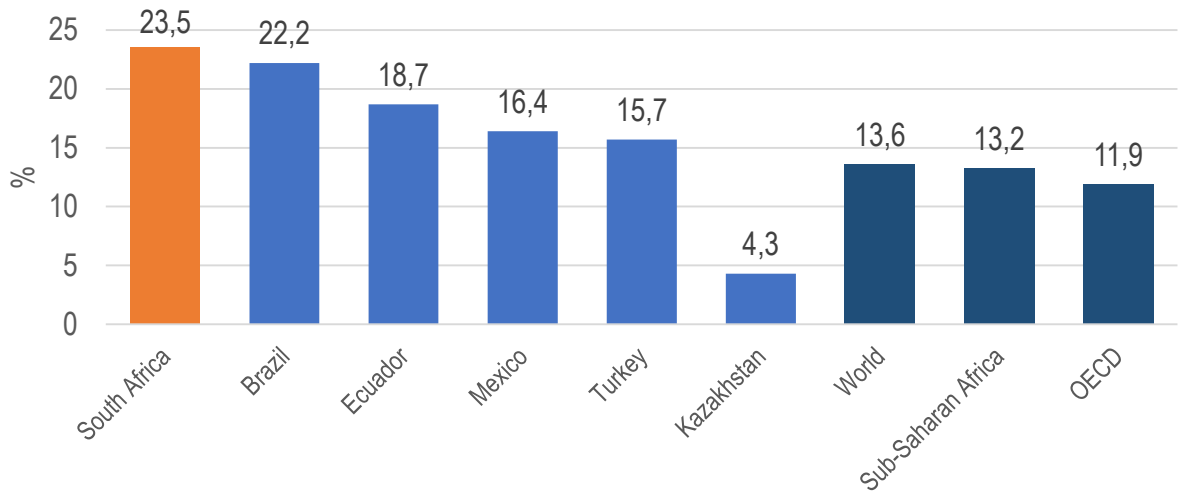

Figure 1.21. Proportion of people living below 50 percent of median income, 2014

1.2.5 Poverty headcount ratio at national poverty lines (% of population)

National poverty headcount ratio is the percentage of the population living below the national poverty line(s). National estimates are based on population-weighted subgroup estimates from household surveys. For economies for which the data are from EU-SILC, the reported year is the income reference year, which is the year before the survey year.

Poverty headcount ratio among the population is measured based on national (i.e., country-specific) poverty lines. A country may have a unique national poverty line or separate poverty lines for rural and urban areas, or for different geographic areas to reflect differences in the cost of living or sometimes to reflect differences in diets and consumption baskets. In South Africa, more than half of the population (i.e. 55.5 per cent) lives under the poverty line. This is again more than the other benchmark countries, above the World and Sub-Saharan Africa averages (Figure 1.22 & 1.23).

Source: World Bank, Global Poverty Working Group. Data are compiled from official government sources or are computed by World Bank staff using national (i.e., country–specific) poverty lines.

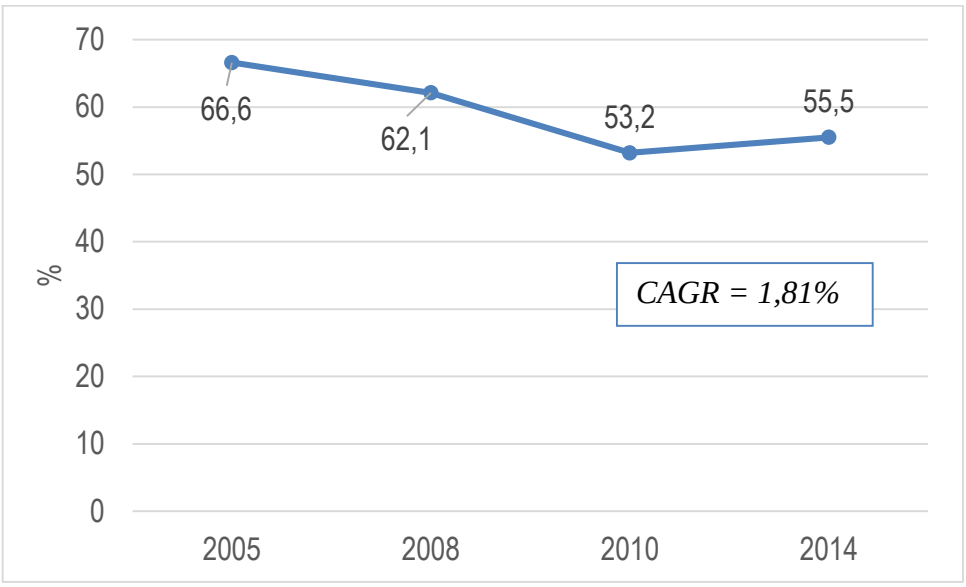

Figure 1.22. Poverty headcount ratio at national poverty line of South Africa, % of population

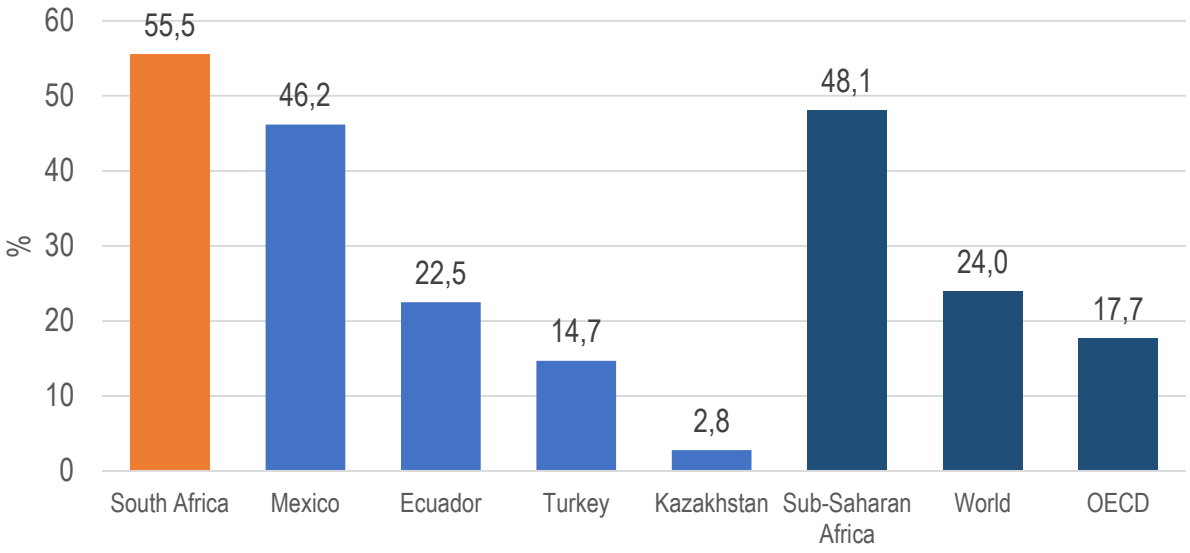

Figure 1.23. Poverty headcount ratio at national poverty lines, 2014

1.2.6 Poverty headcount ratio at $3.20 a day (2011 PPP) (% of population)

Poverty headcount ratio at $3.20 a day is the percentage of the population living on less than $3.20 a day at 2011 international prices. As a result of revisions in PPP exchange rates, poverty rates for individual countries cannot be compared with poverty rates reported in earlier editions.

International comparisons of poverty estimates entail both conceptual and practical problems. Countries have different definitions of poverty, and consistent comparisons across

countries can be difficult. Local poverty lines tend to have higher purchasing power in rich countries, where more generous standards are used, than in poor countries. In South Africa, 37.3 per cent of the population lives on $3.20 a day. Considerable progress has been made since the year 2000, when 53.2 per cent of population lived on the same amount (Figure 1.24). With the latest figure, South Africa does better than the Sub-Saharan Africa average. However, compared to the World average, and the other benchmark countries, South Africa is not doing any better (Figure 1.25).

Source: World Bank, Development Research Group. Data are based on primary household survey data obtained from government statistical agencies and World Bank country departments. Data for high-income economies are from the Luxembourg Income Study database. For more information and methodology, please see PovcalNet (http://iresearch.worldbank.org/PovcalNet/index.htm).

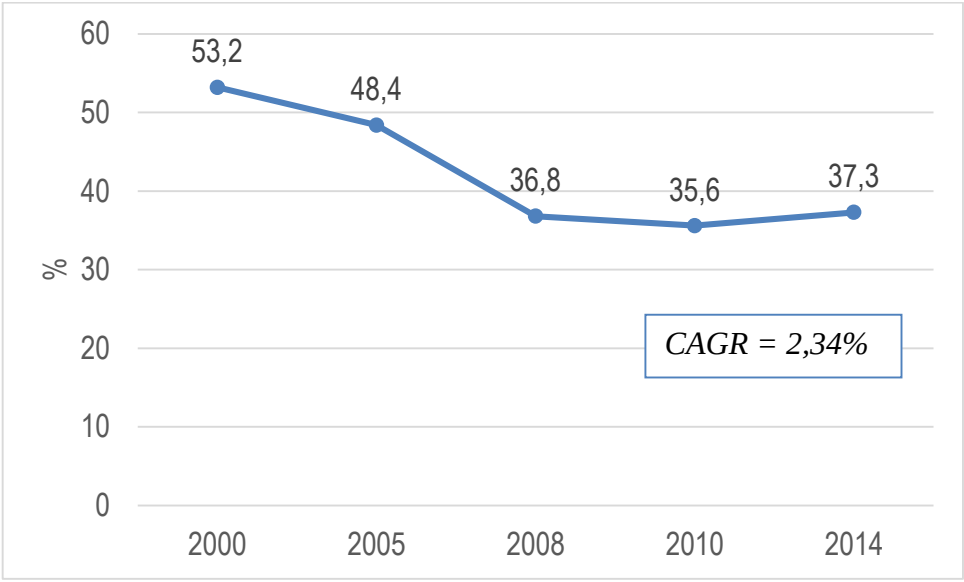

Figure 1.24. Poverty headcount ratio at $3.20 a day (2011 PPP) of South Africa

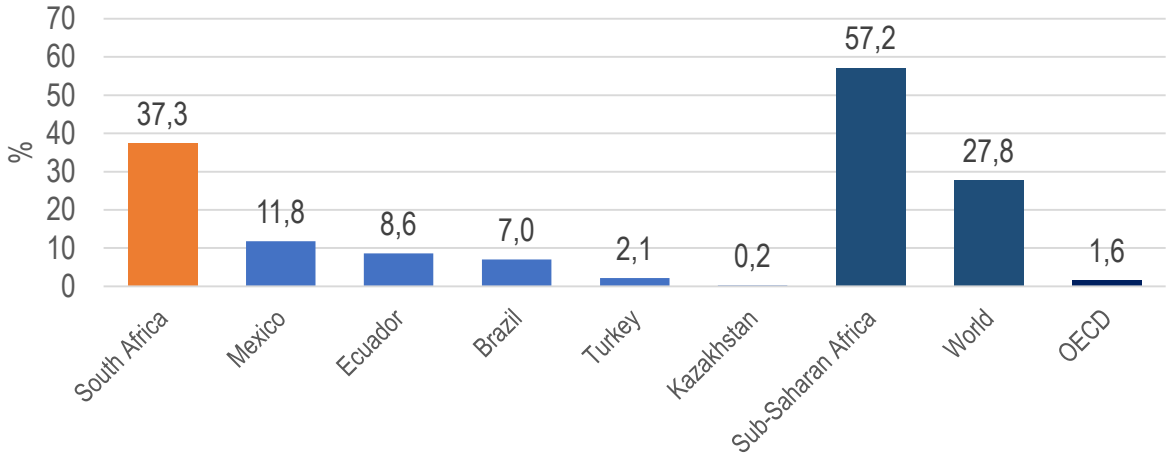

Figure 1.25. Poverty headcount ratio at $3.20 a day (2011 PPP), 2014

1.2.7 Normalized indicators values and a composite index for the «Poverty alleviation» factor

When we look at the normalized indicator values for all the figures above South Africa is performing very low in terms of Gini index, income distribution and poverty headcount. In terms of population living in slums, the country has a relatively better position. In terms of the combined index, South Africa's overall poverty alleviation index is well below the countries analysed (Figure 1.26).

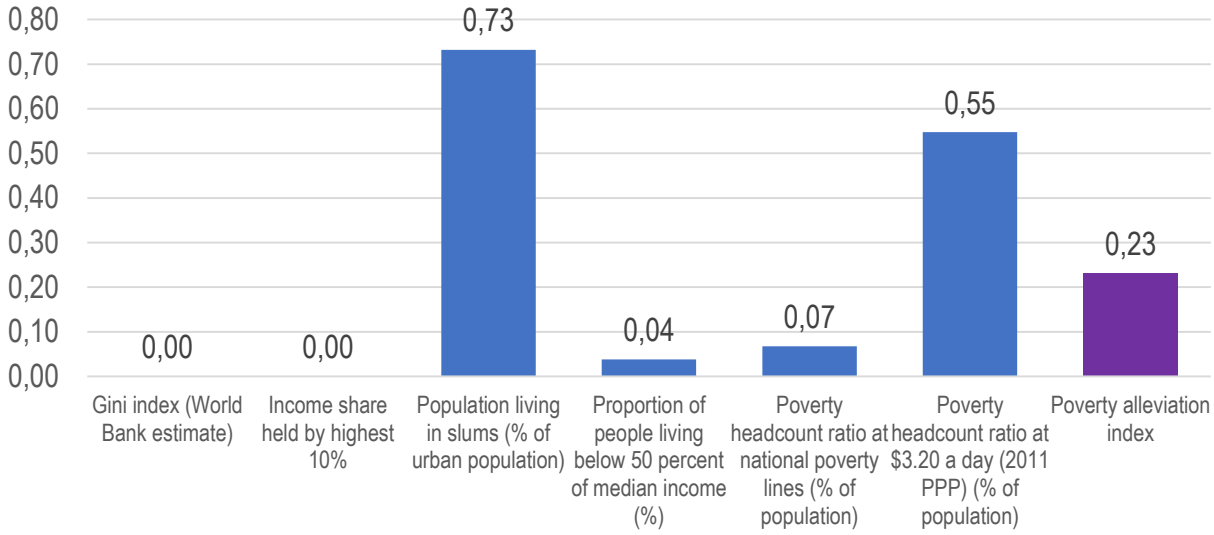

Figure 1.26. Normalized indicators values and a composite index for the «Poverty alleviation» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.3 High quality health care services

1.3.1 Mortality rate, infant (per 1,000 live births)

The main sources of mortality data are vital registration systems and direct or indirect estimates based on sample surveys or censuses. A "complete" vital registration system - covering at least 90 percent of vital events in the population - is the best source of age-specific mortality data.

Estimates of neonatal, infant, and child mortality tend to vary by source and method for a given time and place. Years for available estimates also vary by country, making comparisons across countries and over time difficult. To make neonatal, infant, and child mortality estimates comparable and to ensure consistency across estimates by different agencies, the United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), which comprises the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), the World Bank, the United Nations Population Division, and other universities and research institutes, developed and adopted a statistical method that uses all available information to reconcile differences. The method uses statistical models to obtain a best estimate trend line by fitting a country-specific regression model of mortality rates against their reference dates.

South Africa has made a substantial progress in reducing the infant mortality rates from 46.3 per cent to 27.8 per cent in 2018. This figure continues to decline (Figure 1.27). This rates is well below the Sub-Saharan Africa average, and is comparable to the World average, however, is the highest compared to the other benchmark countries (Figure 1.28).

Source: Estimates developed by the UN Inter-agency Group for Child Mortality Estimation (UNICEF, WHO, World Bank, UN DESA Population Division) at www.childmortality.org.

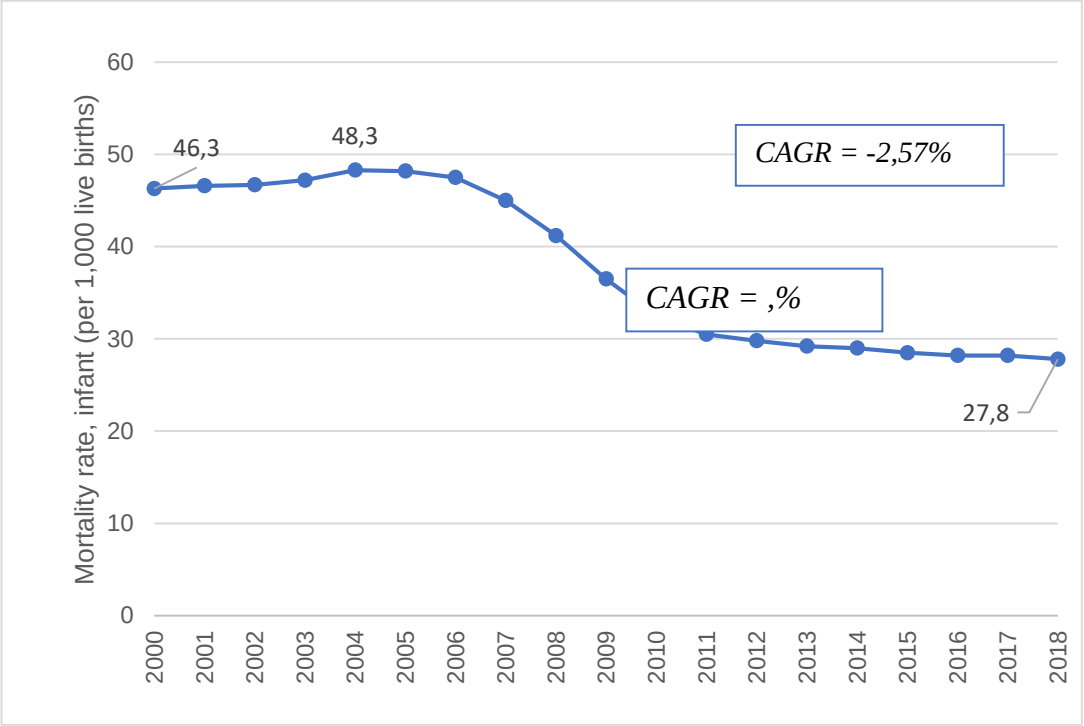

Figure 1.27. Infant mortality rate of South Africa

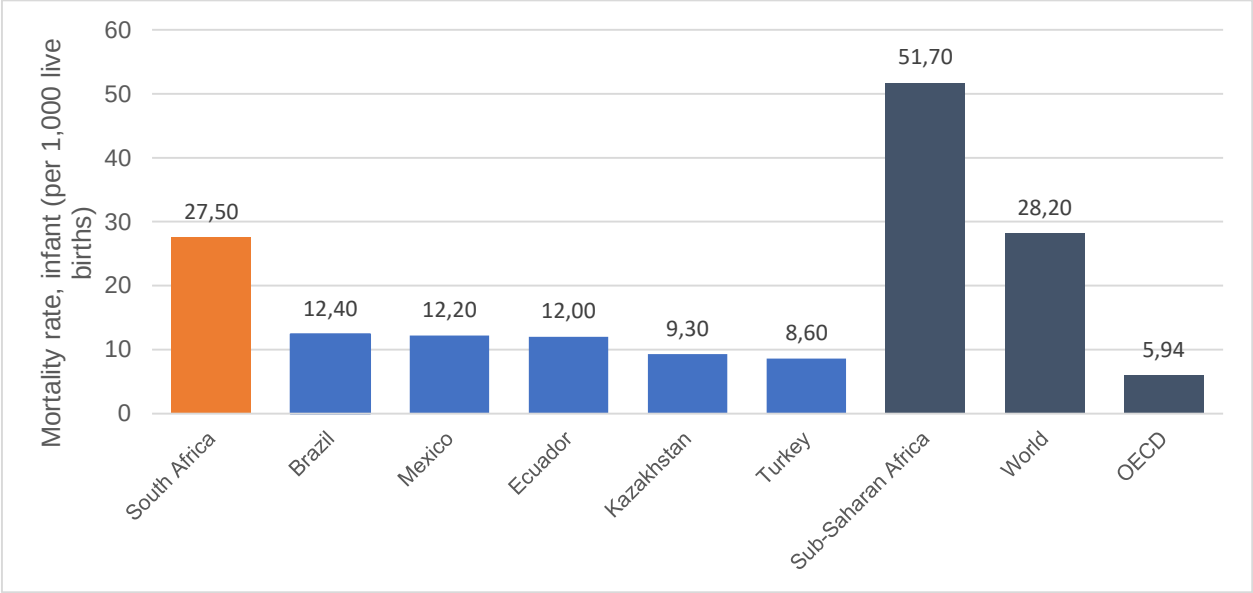

Figure 1.28. Infant mortality rate, 2018

1.3.2 Tuberculosis case detection rate (%, all forms)

Tuberculosis case detection rate (all forms) is the number of new and relapse tuberculosis cases notified to WHO each year, divided by WHO's estimate of the number of incident tuberculosis cases for the same year, expressed as a percentage. Estimates for all years are

recalculated as new information becomes available and techniques are refined, so they may differ from those published previously.

Tuberculosis is one of the main causes of adult deaths from a single infectious agent in developing countries. This indicator shows the tuberculosis detection rate for all detection methods. Editions before 2010 included the tuberculosis detection rates by DOTS, the internationally recommended strategy for tuberculosis control. Thus, data on the case detection rate from 2010 onward cannot be compared with data in previous editions.

Tuberculosis is still a major health problem in the country. Since the year 2000, tuberculosis detection rate in South Africa has increased from 57 per cent to 76 per cent in 2018 (Figure 1.29). This figure is still low compared to the benchmark countries, but is better than the rates in Sub-Saharan Africa and the World averages (Figure 1.30).

Source: World Health Organization, Global Tuberculosis Report.

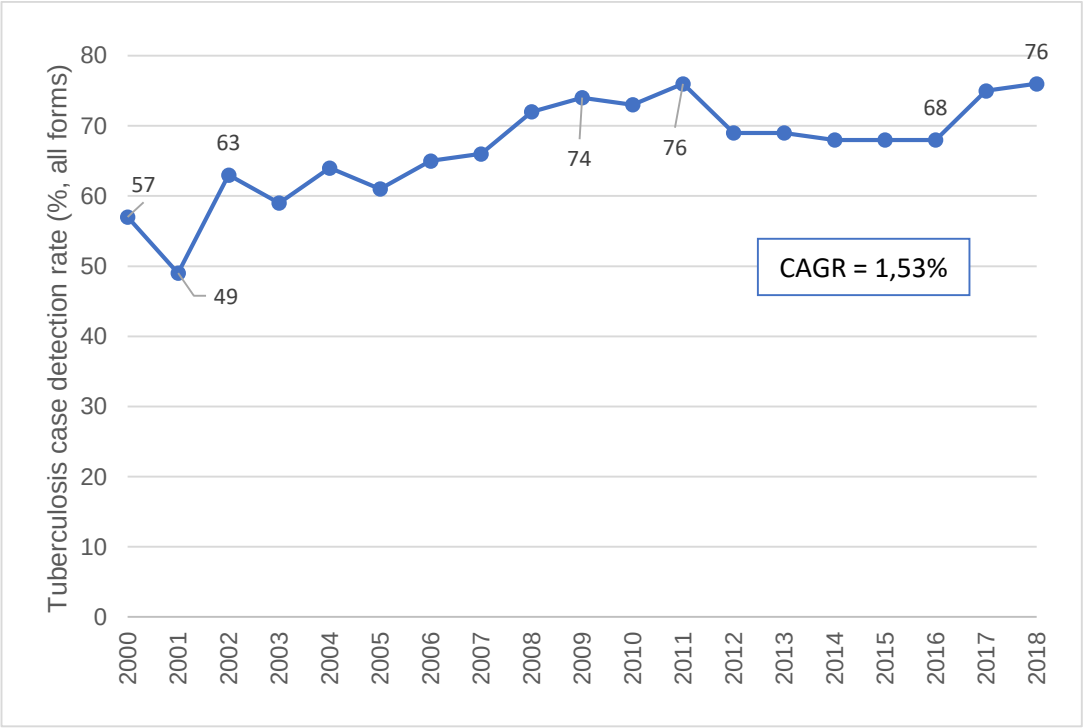

Figure 1.29. Tuberculosis case detection rate of South Africa

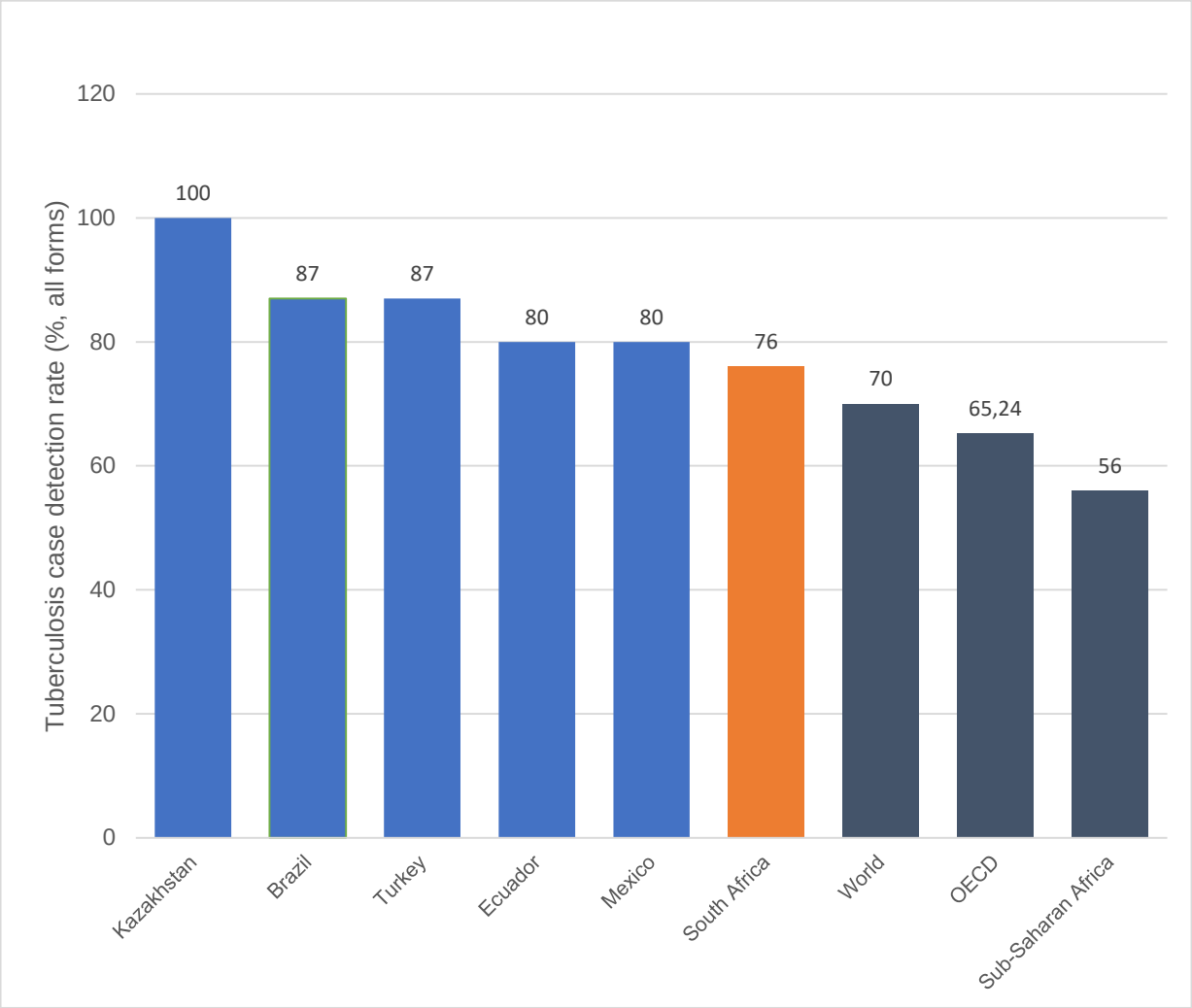

Figure 1.30. Tuberculosis case detection rate, 2018

1.3.3 Immunization, DPT (% of children ages 12-23 months)

Child immunization, DPT, measures the percentage of children ages 12-23 months who received DPT vaccinations before 12 months or at any time before the survey. A child is considered adequately immunized against diphtheria, pertussis (or whooping cough), and tetanus (DPT) after receiving three doses of vaccine.

Governments in developing countries usually finance immunization against measles and diphtheria, pertussis (whooping cough), and tetanus (DTP) as part of the basic public health package. The data shown here are based on an assessment of national immunization coverage rates by the WHO and UNICEF. The assessment considered both administrative data from service providers and household survey data on children's immunization histories. Based on the data available, consideration of potential biases, and contributions of local experts, the most likely true level of immunization coverage was determined for each year.

The immunization rate in South Africa has remained relatively stable around 70 per cent. This rate is less than most of the benchmark countries except Brazil and below the world average (Figure 1.31 & 1.32).

Source: WHO and UNICEF (http://www.who.int/immunization/monitoring_surveillance/en/).

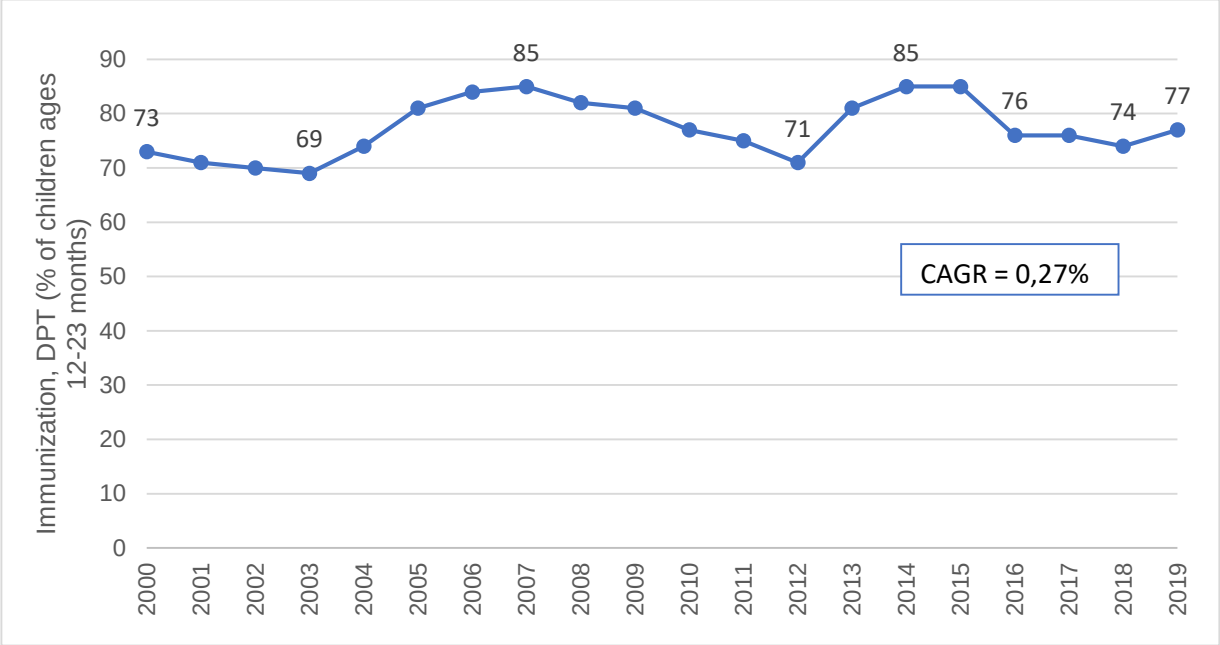

Figure 1.31. Immunization of South Africa (DPT)

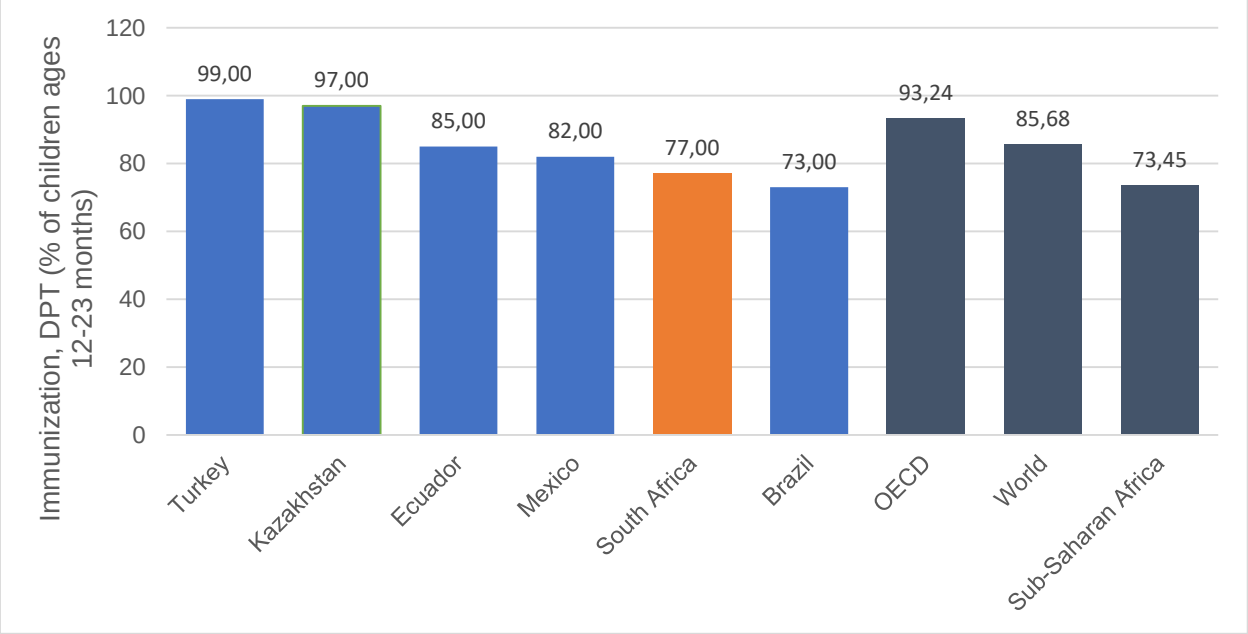

Figure 1.32. Immunization (DPT), 2018

1.3.4 Current health expenditure (% of GDP)

Level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. This indicator does not include capital health expenditures such as buildings, machinery, IT, and stocks of vaccines for emergency or outbreaks.

The health expenditure estimates have been prepared by the World Health Organization under the framework of the System of Health Accounts 2011 (SHA 2011). The Health SHA 2011 tracks all health spending in each country over a defined period regardless of the entity or institution that financed and managed that spending. It generates consistent and comprehensive data on health spending in a country, which in turn can contribute to evidence-based policymaking.

Health expenditure in South Africa has increased in the last decades. However, this increase is just about 1 per cent of the GDP since the year 2000 and has reached to 8.1 per cent in 2017. This figure is slightly below the World average, but significantly higher than the Sub-Saharan Africa average (Figure 1.33 & 1.34).

Source: World Health Organization Global Health Expenditure database (http://apps.who.int/nha/database).

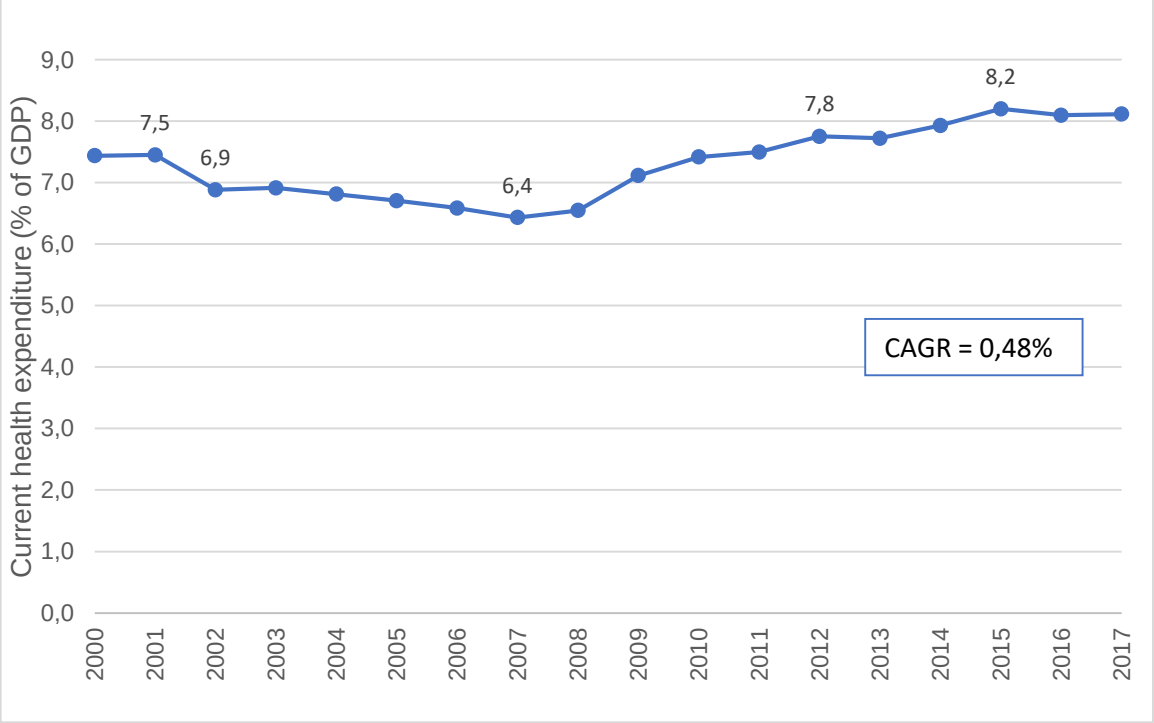

Figure 1.33. Current health expenditure of South Africa

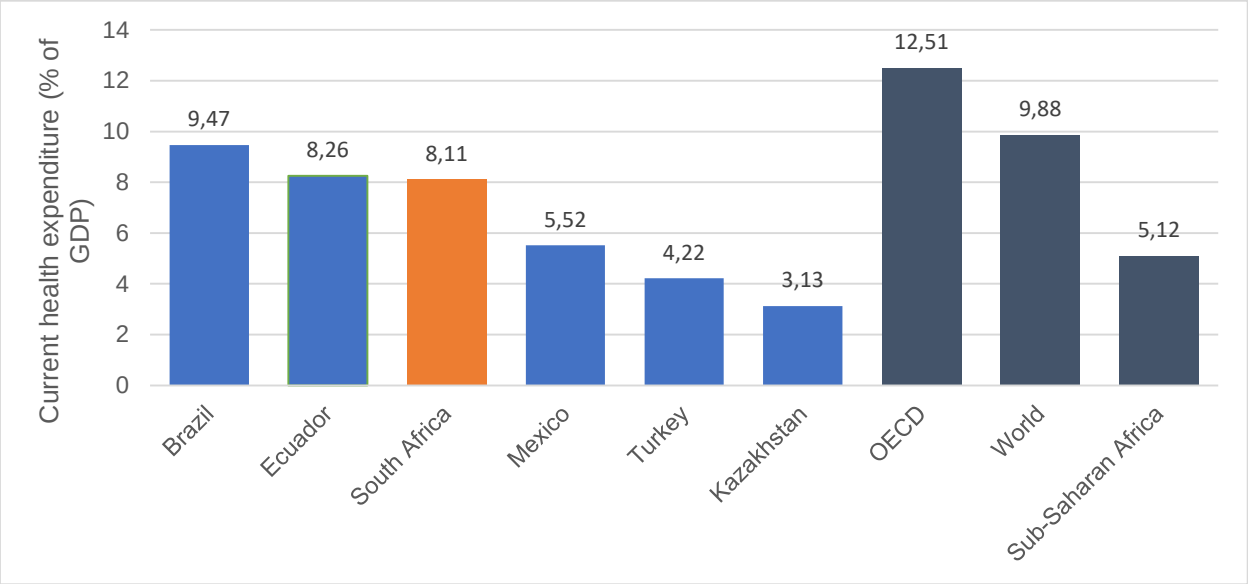

Figure 1.34. Current health expenditure, 2017

1.3.5 Current health expenditure per capita, PPP (current international $)

Current expenditures on health per capita expressed in international dollars at purchasing power parity (PPP time series based on ICP2011 PPP).

The health expenditure estimates have been prepared by the World Health Organization under the framework of the System of Health Accounts 2011 (SHA 2011). The Health SHA 2011 tracks all health spending in each country over a defined period regardless of the entity or institution that financed and managed that spending. It generates consistent and comprehensive data on health spending in a country, which in turn can contribute to evidence-based policymaking.

Similar to the increasing overall healthcare expenditure, per capita health expenditure in South Africa is also increasing. Since the year 2000, the healthcare expenditure per capita increased almost two fold. However, this rate is still below most of the benchmark countries except Brazil, and is also below the World average (Figure 1.35 & 1.36).

Source: World Health Organization Global Health Expenditure database (http://apps.who.int/nha/database).

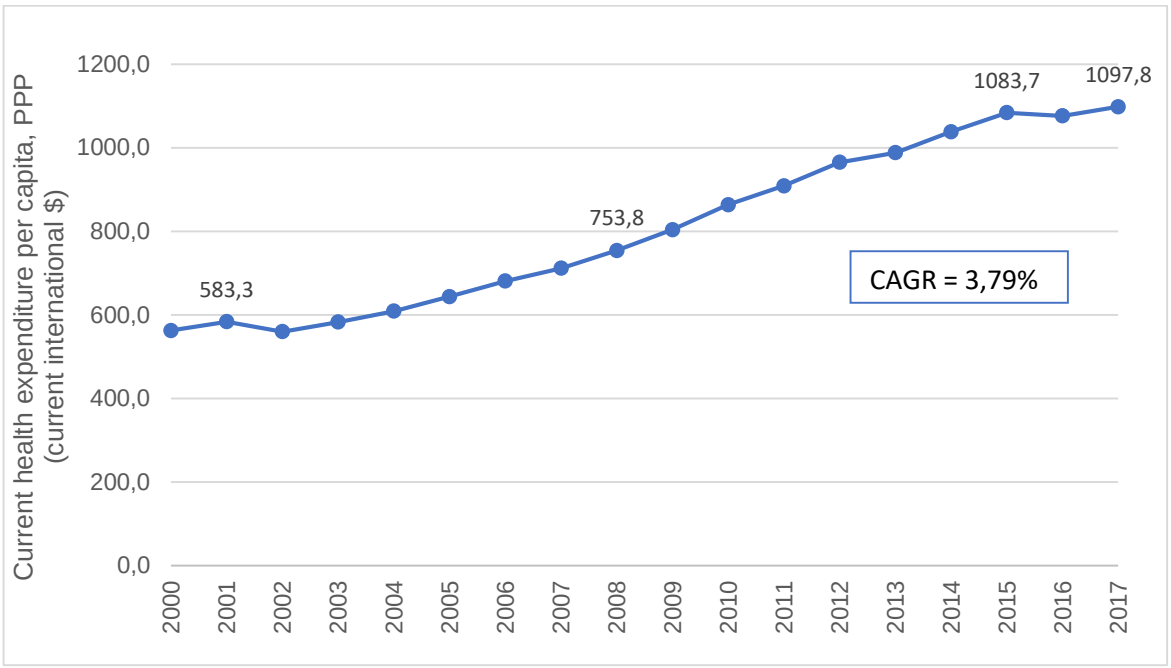

Figure 1.35. Current health expenditure per capita of South Africa (PPP)

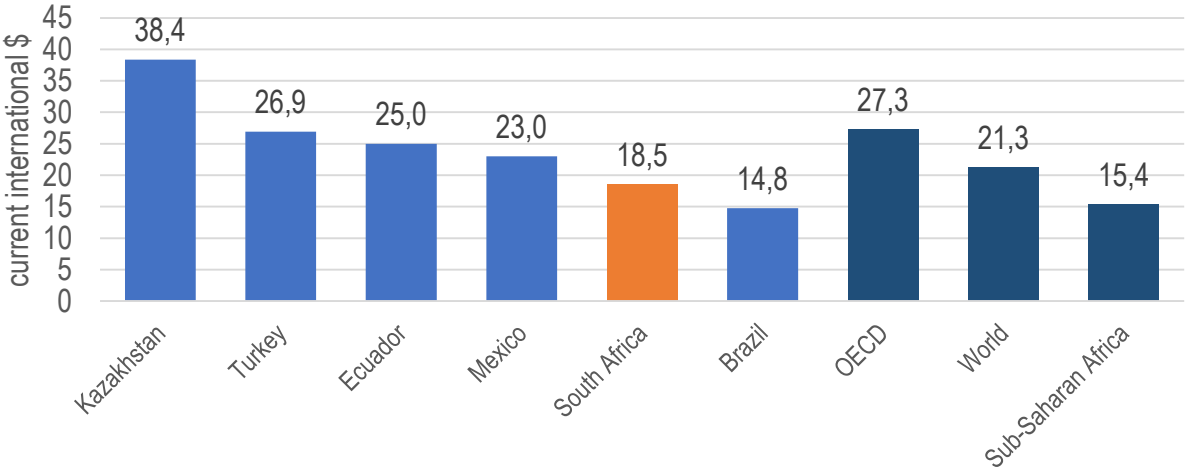

Figure 1.36. Current health expenditure per capita (PPP), 2017

1.3.6 Life expectancy at birth, total (years)

Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.

Life expectancy at birth used here is the average number of years a newborn is expected to live if mortality patterns at the time of its birth remain constant in the future. It reflects the overall mortality level of a population and summarizes the mortality pattern that prevails across all age groups each year. It is calculated in a period life table which provides a snapshot of a population's

mortality pattern at a given time. It therefore does not reflect the mortality pattern that a person experiences during his/her life, which can be calculated in a cohort life table.

High mortality in young age groups significantly lowers the life expectancy at birth. But if a person survives his/her childhood of high mortality, he/she may live much longer. For example, in a population with a life expectancy at birth of 50, there may be few people dying at age 50. The life expectancy at birth may be low due to the high childhood mortality so that once a person survives his/her childhood; he/she may live much longer than 50 years.

Overall life expectancy in South Africa has been increasing from 53 years in 2004 to 64 in 2018. Although this is a positive trend, it is still well below the other benchmark countries and the World average, which is 72.56 years (Figure 1.37 & 1.38). This trend shows that South Africa has still much to do to extend the life expectancy of the country's population.

Source: (1) United Nations Population Division. World Population Prospects: 2019 Revision or derived from male and female life expectancy at birth from sources such as: (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) United Nations Statistical Division. Population and Vital Statistics Report (various years), (5) U.S. Census Bureau: International Database, and (6) Secretariat of the Pacific Community: Statistics and Demography Programme.

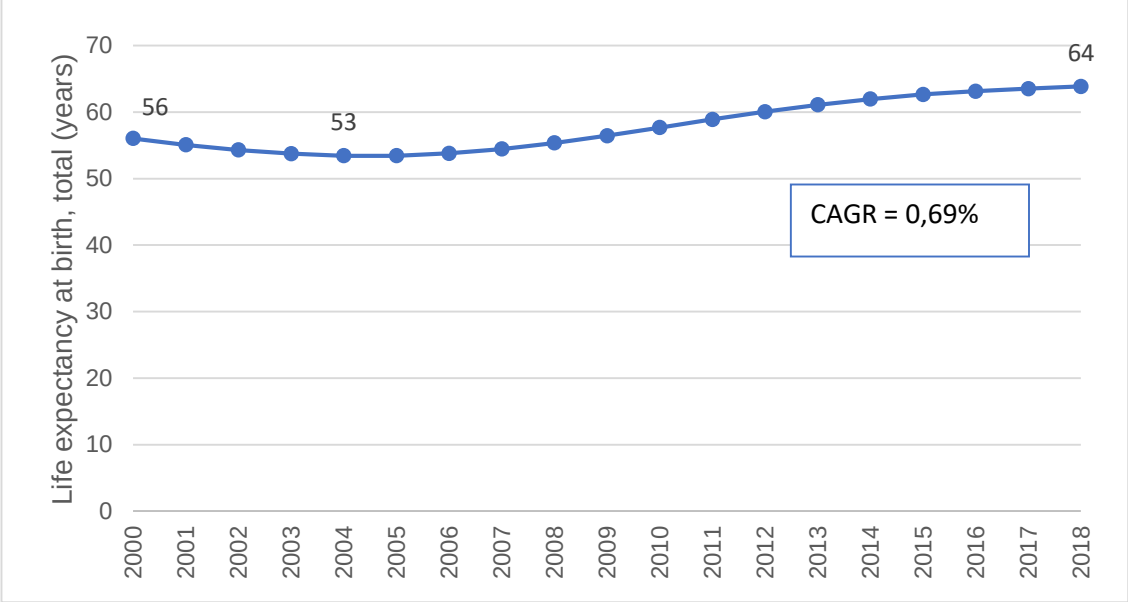

Figure 1.37. Life expectancy at birth in South Africa

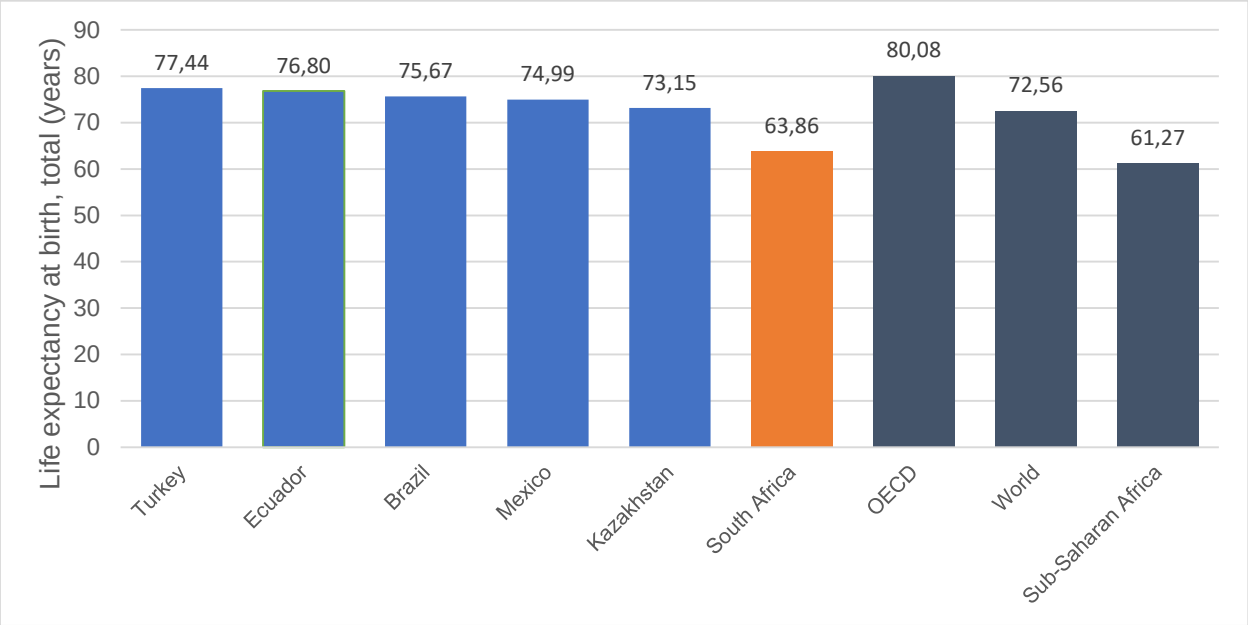

Figure 1.38. Life expectancy at birth, 2019

1.3.7 Normalized indicators values and composite index for the «High quality health care services» factor

Looking at the normalized indicators, it is seen that South Africa is averaging overall in health care. However, the indicators related to health expenditure per capita, life expectancy at birth and tuberculosis case detection rate are well below the average, where the country is under-performing (Figure 1.37).

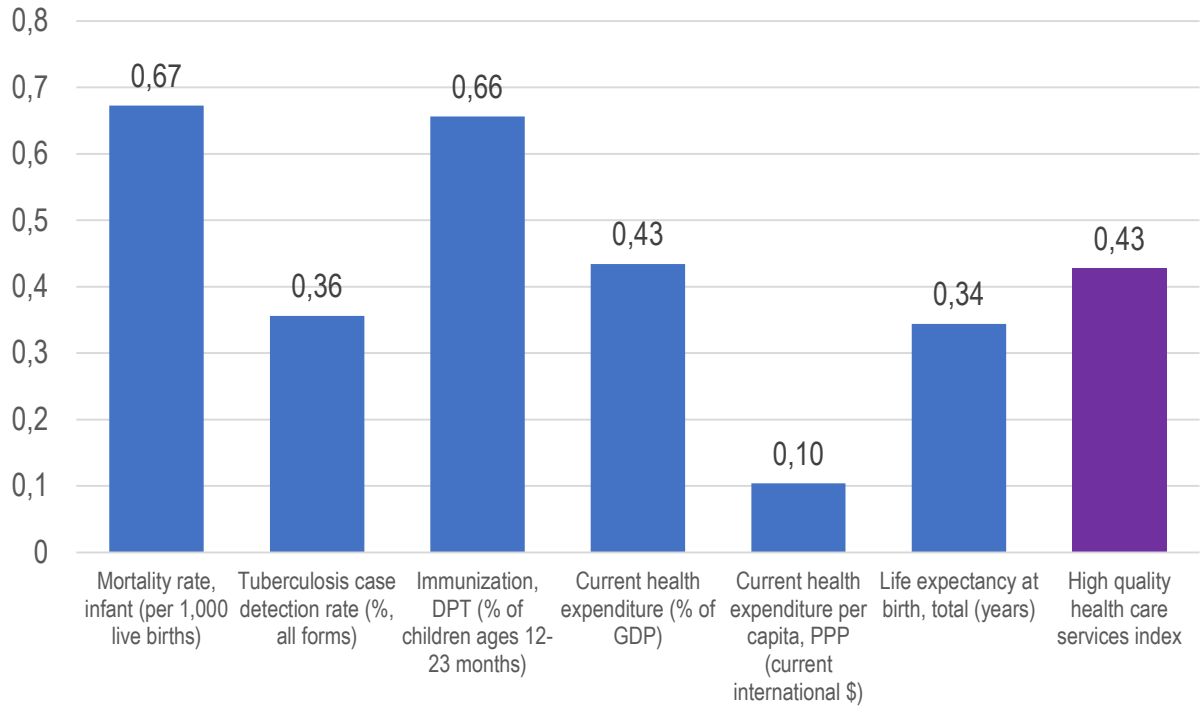

Figure 1.39. Normalized indicators values and a composite index for the «High quality health care services» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.4 Carbon emission reduction

1.4.1 CO2 emissions (kg per 2017 PPP $ of GDP)

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

Carbon dioxide emissions, largely by-products of energy production and use, account for the largest share of greenhouse gases, which are associated with global warming. Anthropogenic carbon dioxide emissions result primarily from fossil fuel combustion and cement manufacturing. In combustion different fossil fuels release different amounts of carbon dioxide for the same level of energy use: oil releases about 50 percent more carbon dioxide than natural gas, and coal releases about twice as much. Cement manufacturing releases about half a metric ton of carbon dioxide for each metric ton of cement produced. Carbon dioxide emissions are often calculated and reported as elemental carbon. The values were converted to actual carbon dioxide mass by multiplying them by 3.667 (the ratio of the mass of carbon to that of carbon dioxide).

The level of CO2 emissions kg per capita in South Africa has been going down steadily in the last couple of decades. Although this is a positive sign, compared to the other countries in the world, there is still much more progress need to be made (Figure 1.40 & 1.41)

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

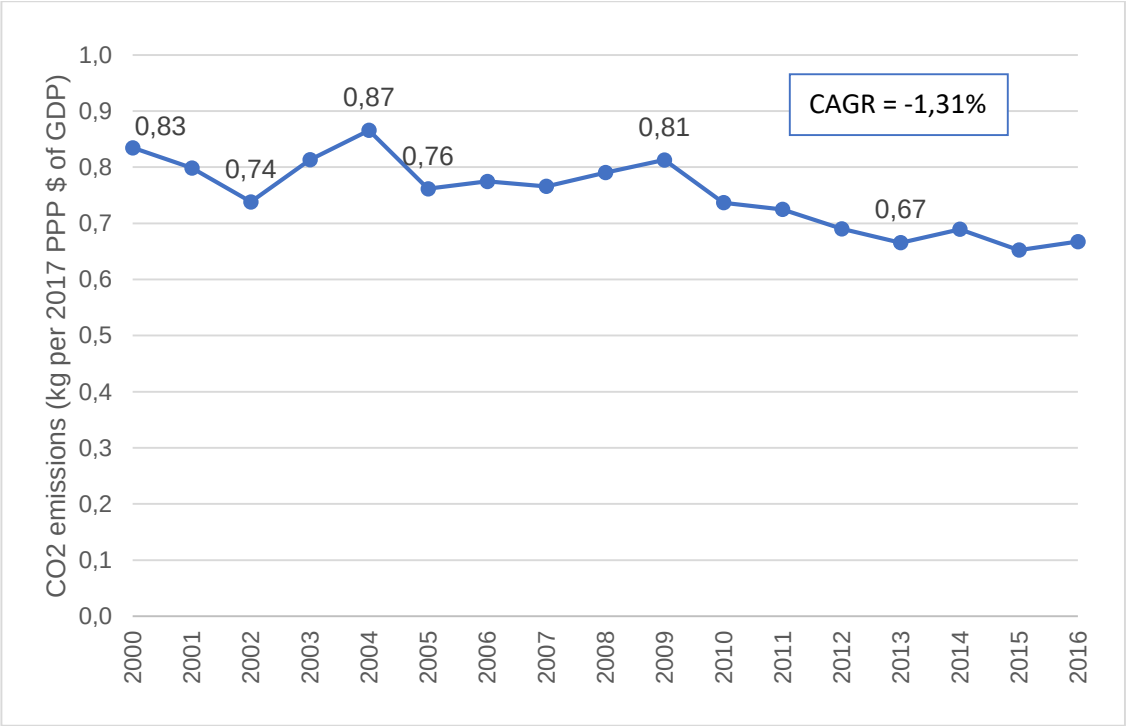

Figure 1.40. CO2 emissions (2017 PPP) of South Africa

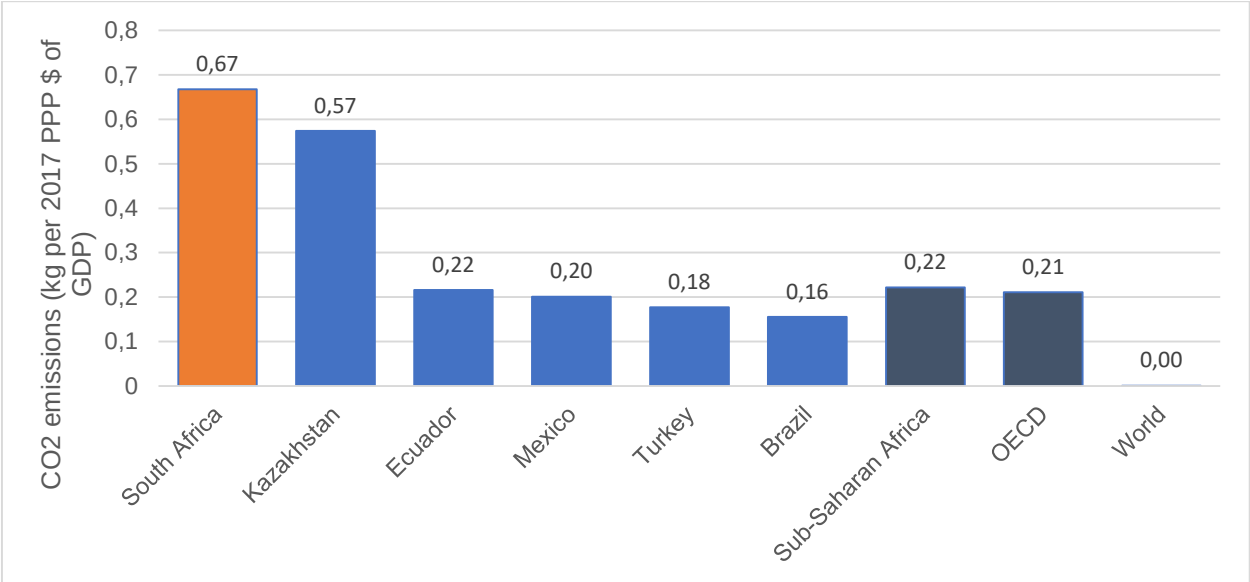

Figure 1.41. CO2 emissions (kg per 2017 PPP $ of GDP), 2016

1.4.2 CO2 emissions (metric tons per capita)

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.

Carbon dioxide emissions, largely by-products of energy production and use, account for the largest share of greenhouse gases, which are associated with global warming. Anthropogenic carbon dioxide emissions result primarily from fossil fuel combustion and cement manufacturing. In combustion different fossil fuels release different amounts of carbon dioxide for the same level of energy use: oil releases about 50 percent more carbon dioxide than natural gas, and coal releases about twice as much. Cement manufacturing releases about half a metric ton of carbon dioxide for each metric ton of cement produced. Data for carbon dioxide emissions include gases from the burning of fossil fuels and cement manufacture but excludes emissions from land use such as deforestation.

CO2 emissions metric tons per capita have remained stable since the year 2000. With these figures South Africa ranks second after Kazakhstan and are comperable to the OECD countries (Figure 1.42 & 1.43).

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

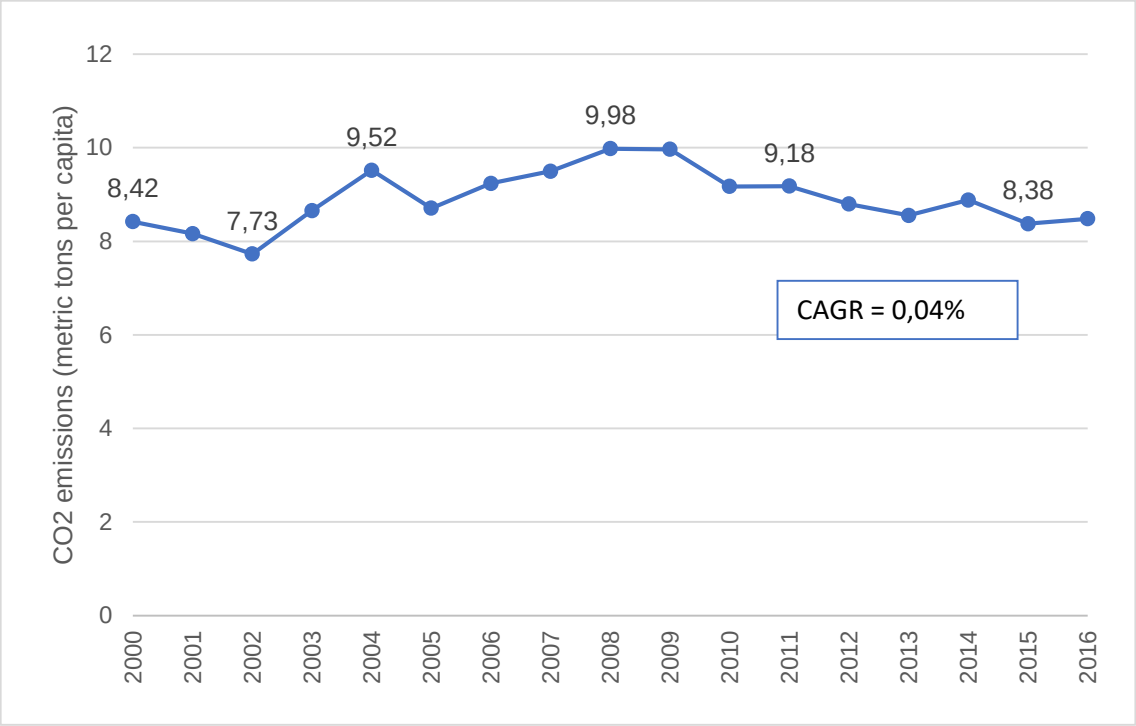

Figure 1.42. CO2 emissions of South Africa

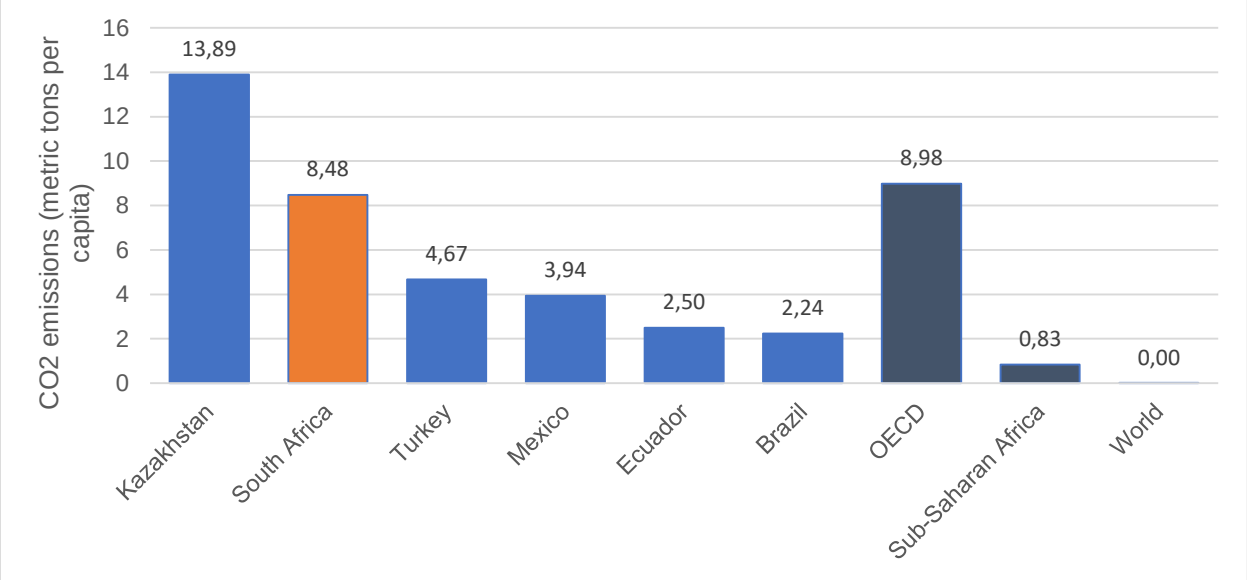

Figure 1.43. CO2 emissions (metric tons per capita), 2016

1.4.3 CO2 emissions from electricity and heat production, total (% of total fuel combustion)

CO2 emissions from electricity and heat production is the sum of three IEA categories of CO2 emissions: (1) Main Activity Producer Electricity and Heat which contains the sum of emissions from main activity producer electricity generation, combined heat and power generation and heat plants. Main activity producers (formerly known as public utilities) are defined as those

undertakings whose primary activity is to supply the public. They may be publicly or privately owned. This corresponds to IPCC Source/Sink Category 1 A 1 a. For the CO2 emissions from fuel combustion (summary) file, emissions from own on-site use of fuel in power plants (EPOWERPLT) are also included. (2) Unallocated Autoproducers which contains the emissions from the generation of electricity and/or heat by autoproducers. Autoproducers are defined as undertakings that generate electricity and/or heat, wholly or partly for their own use as an activity which supports their primary activity. They may be privately or publicly owned. In the 1996 IPCC Guidelines, these emissions would normally be distributed between industry, transport, and "other" sectors. (3) Other Energy Industries contains emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries. This corresponds to the IPCC Source/Sink Categories 1 A 1 b and 1 A 1 c. According to the 1996 IPCC Guidelines, emissions from coke inputs to blast furnaces can either be counted here or in the Industrial Processes source/sink category. Within detailed sectoral calculations, certain non-energy processes can be distinguished. In the reduction of iron in a blast furnace through the combustion of coke, the primary purpose of the coke oxidation is to produce pig iron and the emissions can be considered as an industrial process. Care must be taken not to double count these emissions in both Energy and Industrial Processes. In the IEA estimations, these emissions have been included in this category.

CO2 emission generation from electricity and heat production is also high in South Africa, and has remained the same in the past 20 years at the level of 67.5 per cent as percentage of the total fuel consumption. This figure is higer than the benchmark countries as well as the World and Sub-Saharan Africa averages (Figure 1.44 & 1.45).

Source: IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/.

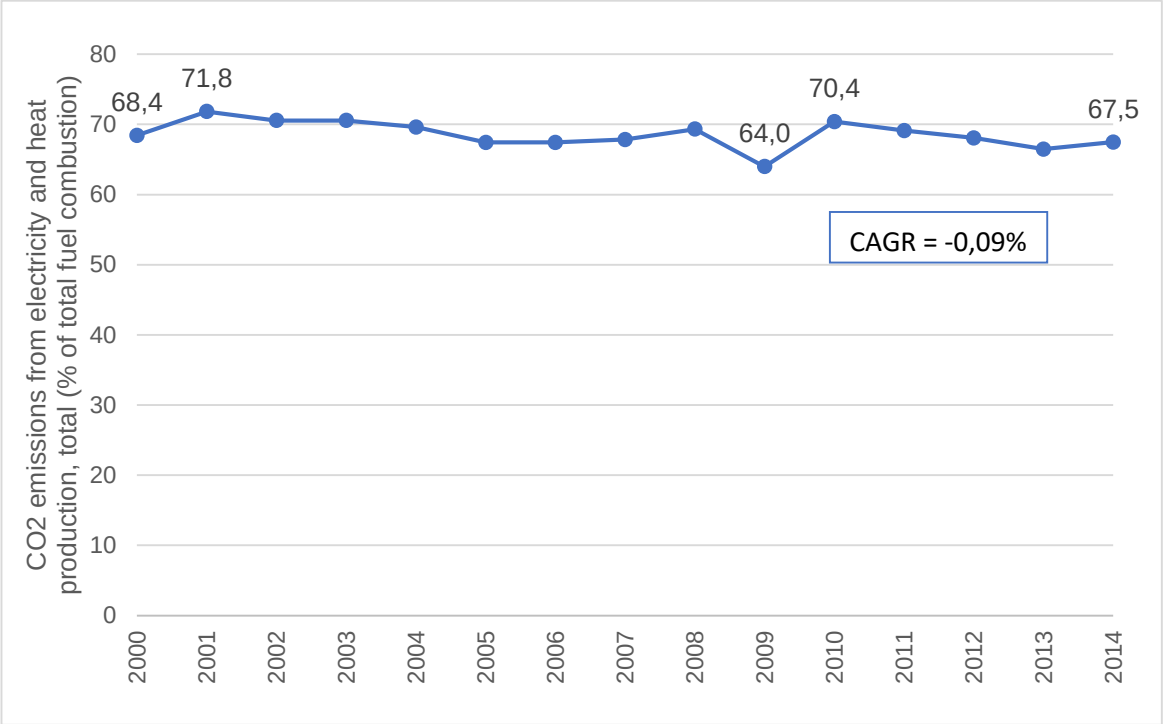

Figure 1.44. Total CO2 emissions from electricity and heat production of South Africa

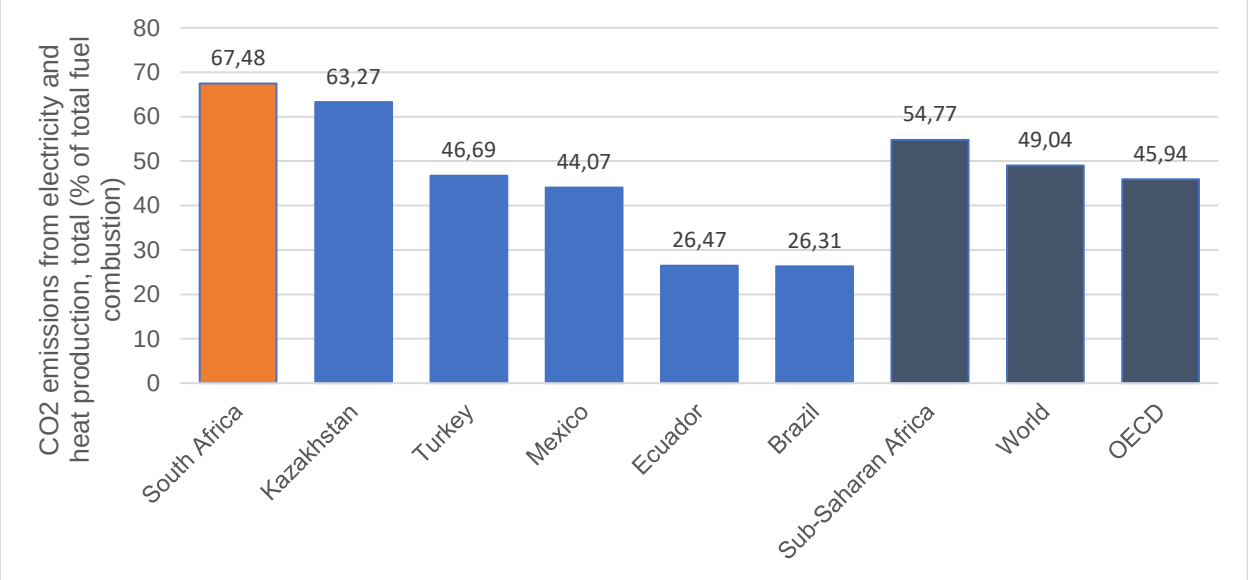

Figure 1.45. Total CO2 emissions from electricity and heat production, 2014

1.4.4 CO2 emissions from gaseous fuel consumption (kt)

Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of natural gas as an energy source.

Carbon dioxide emissions, largely by-products of energy production and use, account for the largest share of greenhouse gases, which are associated with global warming. Anthropogenic carbon dioxide emissions result primarily from fossil fuel combustion and cement manufacturing. In combustion different fossil fuels release different amounts of carbon dioxide for the same level of energy use: oil releases about 50 percent more carbon dioxide than natural gas, and coal releases about twice as much. Cement manufacturing releases about half a metric ton of carbon dioxide for each metric ton of cement produced. Data for carbon dioxide emissions include gases from the burning of fossil fuels and cement manufacture but excludes emissions from land use such as deforestation. Carbon dioxide emissions are often calculated and reported as elemental carbon. The values were converted to actual carbon dioxide mass by multiplying them by 3.667 (the ratio of the mass of carbon to that of carbon dioxide).

South Africa experiences a steady increase inemissions generated by gaseous fuel consumption due to a growing consumption of natural gas. However, the rates are still insignificant compared to the other countries in the World (Figure 1.46 & 1.47).

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

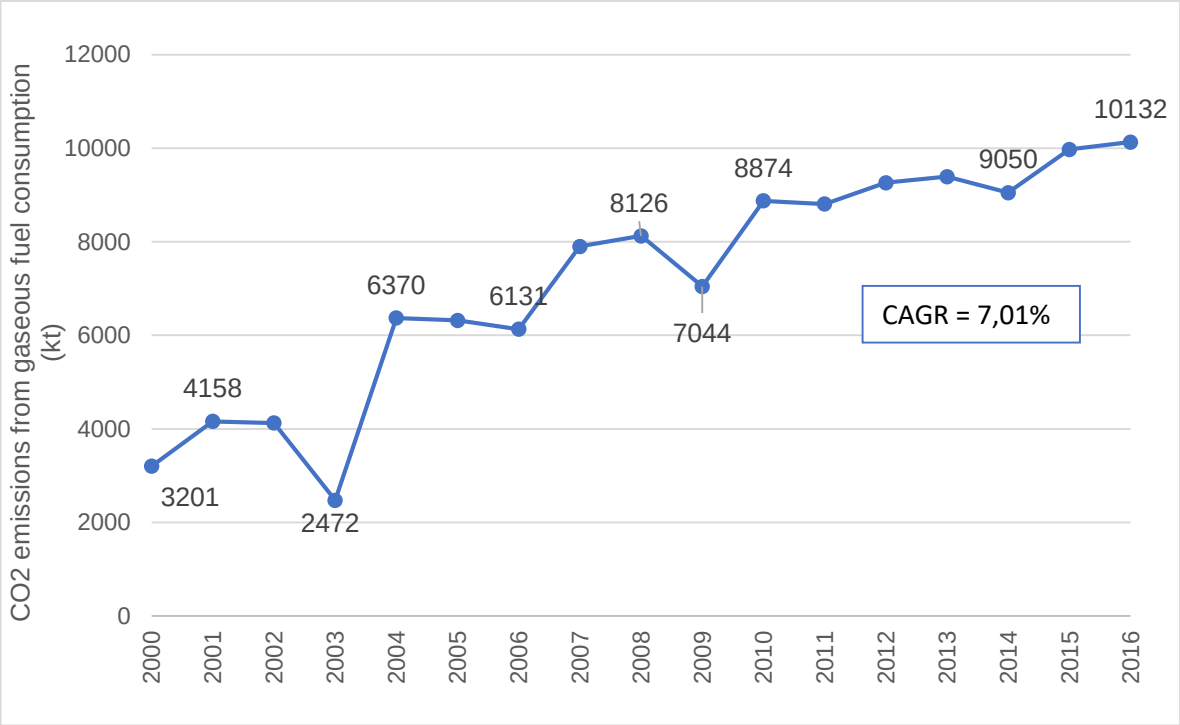

Figure 1.46. CO2 emissions from gaseous fuel consumption of South Africa

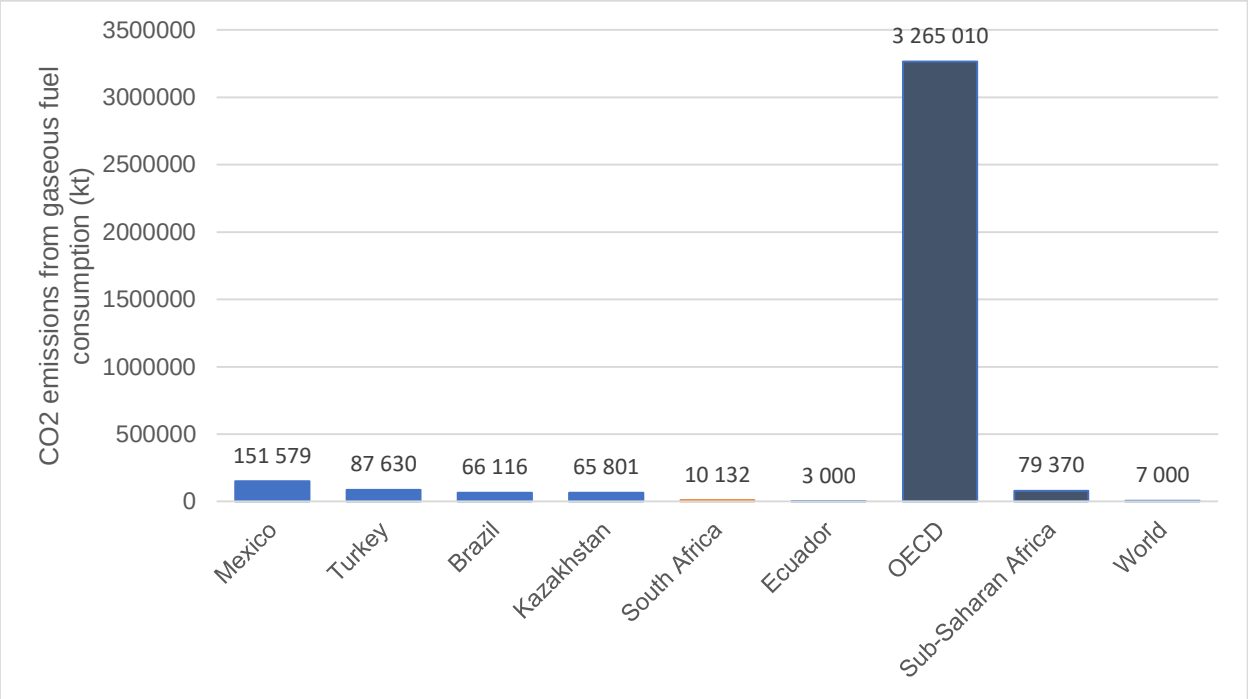

Figure 1.47. CO2 emissions from gaseous fuel consumption, 2016

1.4.5 CO2 emissions from liquid fuel consumption (kt)

Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source.

Carbon dioxide emissions, largely by-products of energy production and use, account for the largest share of greenhouse gases, which are associated with global warming. Anthropogenic carbon dioxide emissions result primarily from fossil fuel combustion and cement manufacturing. In combustion different fossil fuels release different amounts of carbon dioxide for the same level of energy use: oil releases about 50 percent more carbon dioxide than natural gas, and coal releases about twice as much. Cement manufacturing releases about half a metric ton of carbon dioxide for each metric ton of cement produced. Data for carbon dioxide emissions include gases from the burning of fossil fuels and cement manufacture but excludes emissions from land use such as deforestation. Carbon dioxide emissions are often calculated and reported as elemental carbon. The values were converted to actual carbon dioxide mass by multiplying them by 3.667 (the ratio of the mass of carbon to that of carbon dioxide).

CO2 emissions generated by the consumption of liquid fuels have relatively increased during the last two decades with a fluctuating trend. However, with the case of South Africa these

figures are not comparable to the emissions generated by the OECD countries and the Sub-Saharan Africa average (Figure 1.48 & 1.49).

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

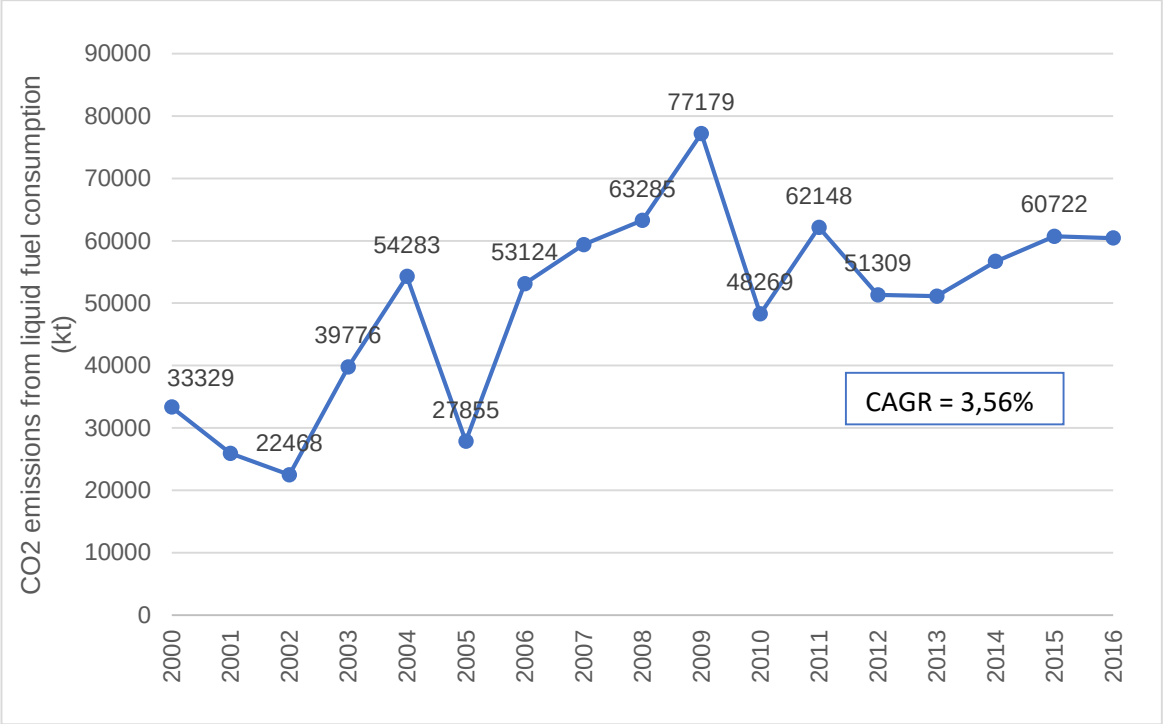

Figure 1.48. CO2 emissions from liquid fuel consumption of South Africa

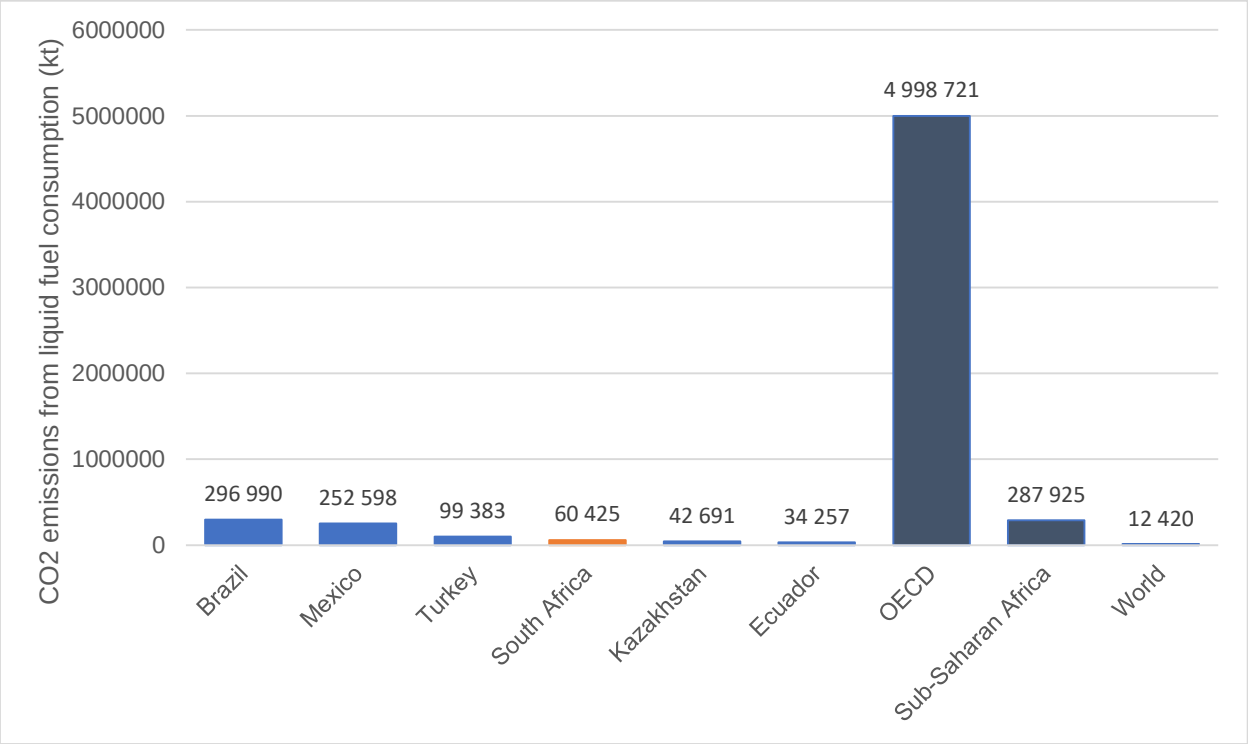

Figure 1.49. CO2 emissions from liquid fuel consumption, 2016

1.4.6 CO2 emissions from solid fuel consumption (% of total)

Carbon dioxide emissions from solid fuel consumption refer mainly to emissions from use of coal as an energy source.

The U.S. Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC) calculates annual anthropogenic emissions from data on fossil fuel consumption (from the United Nations Statistics Division's World Energy Data Set) and world cement manufacturing (from the U.S. Department of Interior's Geological Survey (USGS 2011)). Although estimates of global carbon dioxide emissions are probably accurate within 10 percent (as calculated from global average fuel chemistry and use), country estimates may have larger error bounds. Trends estimated from a consistent time series tend to be more accurate than individual values.

Each year the CDIAC recalculates the entire time series since 1949, incorporating recent findings and corrections. Estimates exclude fuels supplied to ships and aircraft in international transport because of the difficulty of apportioning the fuels among benefiting countries.

Considering South Africa’s energy mix, it is clearly seen that emissions from solid fuel consumption are extremely high – i.e. over 80 per cent kg per PPP USD of GDP with 2017 prices (Figure 1.50). Solid fuel consumption is the highest among the benchmark countries as well as the

World and Sub-Saharan Africa averages (Figure 1.51). This is emphasizing that for a clearer and healthier environment there is an increasing need to increase the share of cleaner energy sources and renewables in the energy mix.

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

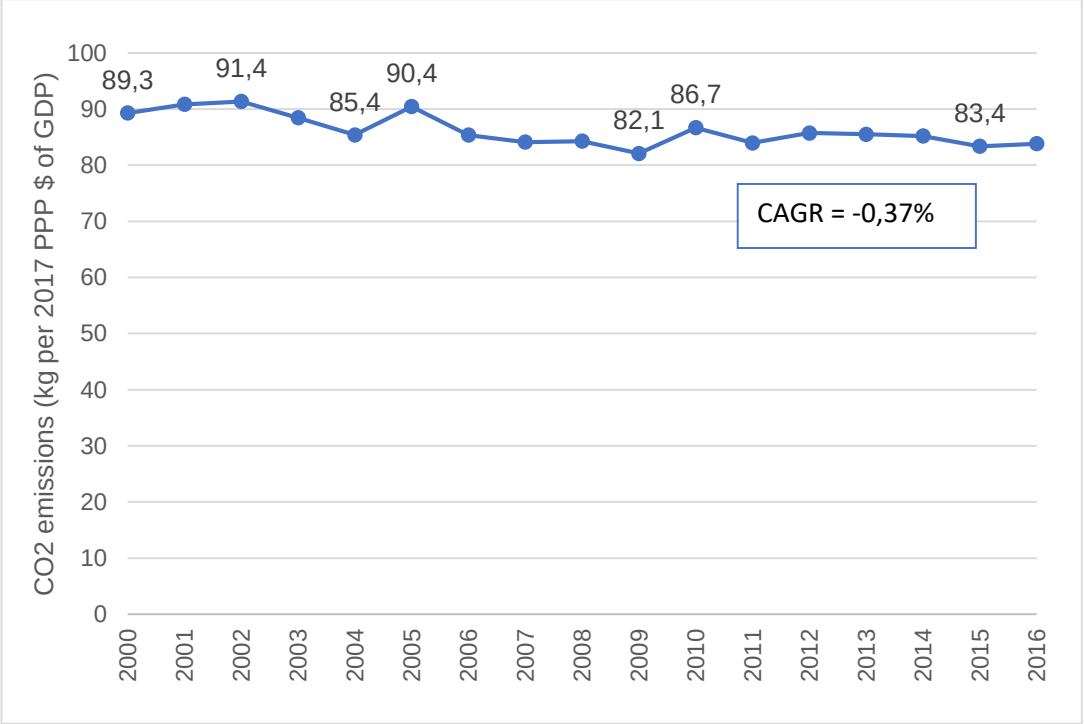

Figure 1.50. CO2 emissions from solid fuel consumption of South Africa

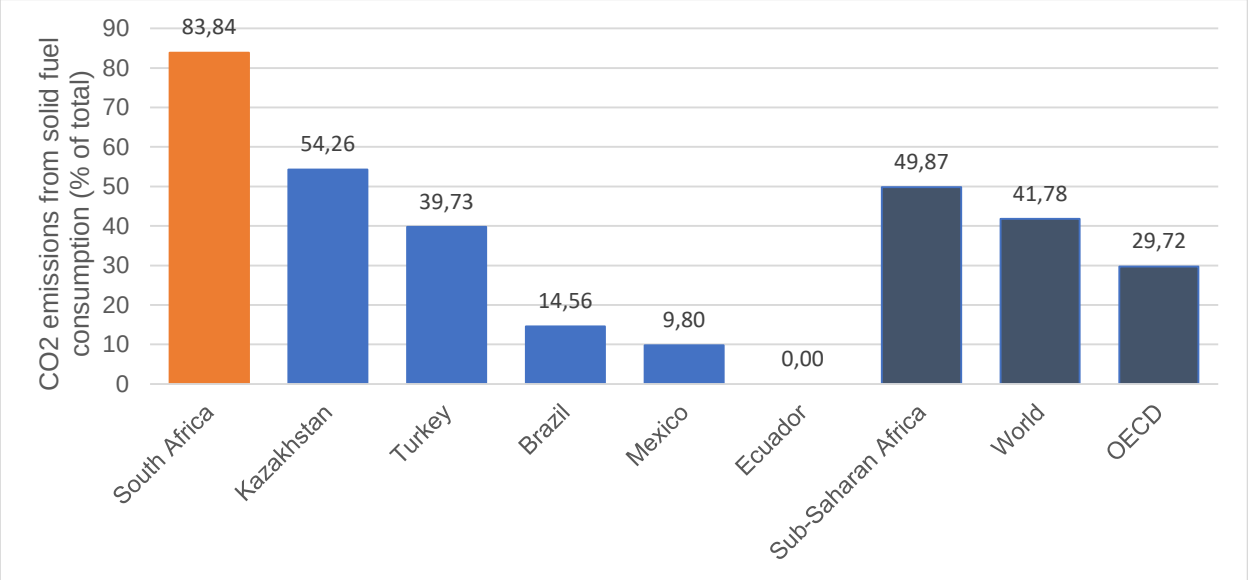

Figure 1.51. CO2 emissions from solid fuel consumption, 2016

1.4.7 Normalized indicators values and composite index for the «Carbon emission reduction» factor

The summary of the aforementioned analysis is presented in Figure 1.52, where South Africa's current energy use and sources are emissions are clearly visible – i.e. the dominance of the emissions by solid fuel consumption, and less dependency on gaseous and liquid fuel consumption compared to other benchmark countries.

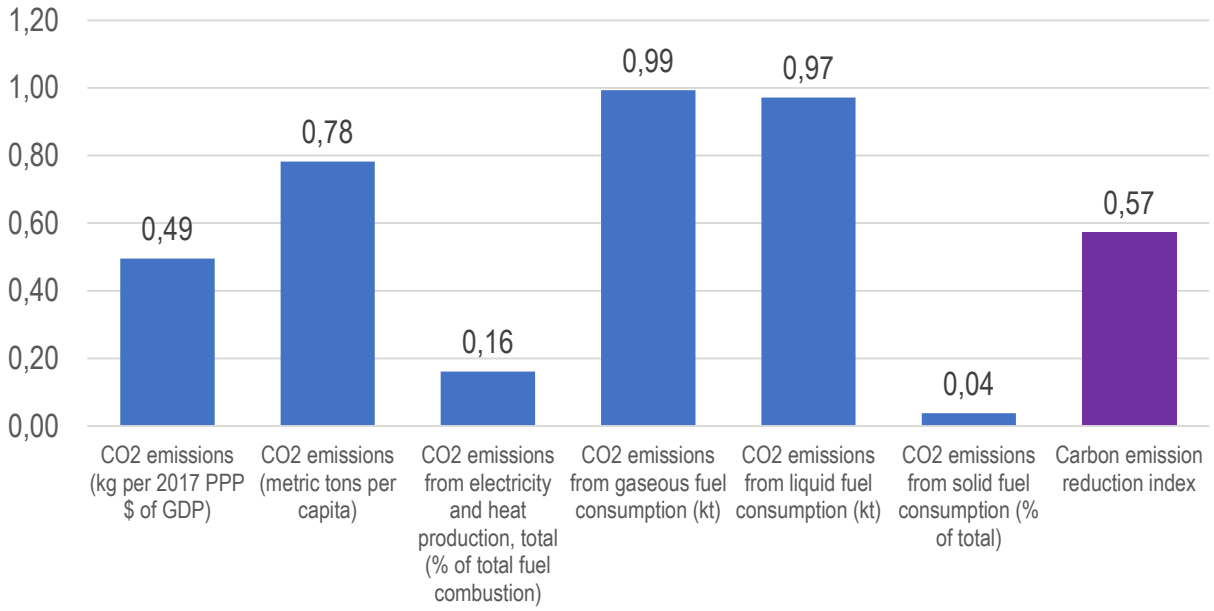

Figure 1.52. Normalized indicators values and a composite index for the «Carbon emission reduction» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.5 Access and supply of clean water

1.5.1 People using at least basic drinking water services (% of population)

The percentage of people using at least basic water services. This indicator encompasses both people using basic water services as well as those using safely managed water services. Basic drinking water services is defined as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.

Data on drinking water, sanitation and hygiene are produced by the Joint Monitoring Programme of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) based on administrative sources, national censuses, and nationally representative household surveys. WHO/UNICEF defines a basic drinking water service as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.

Figure 1.53 illustrates that the number of people accessing clean water services in South Africa is increasing on a continuous bases in the last couple of decades. There is still approximately 10 per cent of the population lacking access to clean water services. According to Figure 1.54, South Africa is leading in terms of providing clean water services to its population among the Sub-Saharan African countries. However, the country is still behind the other benchmark countries.

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org).

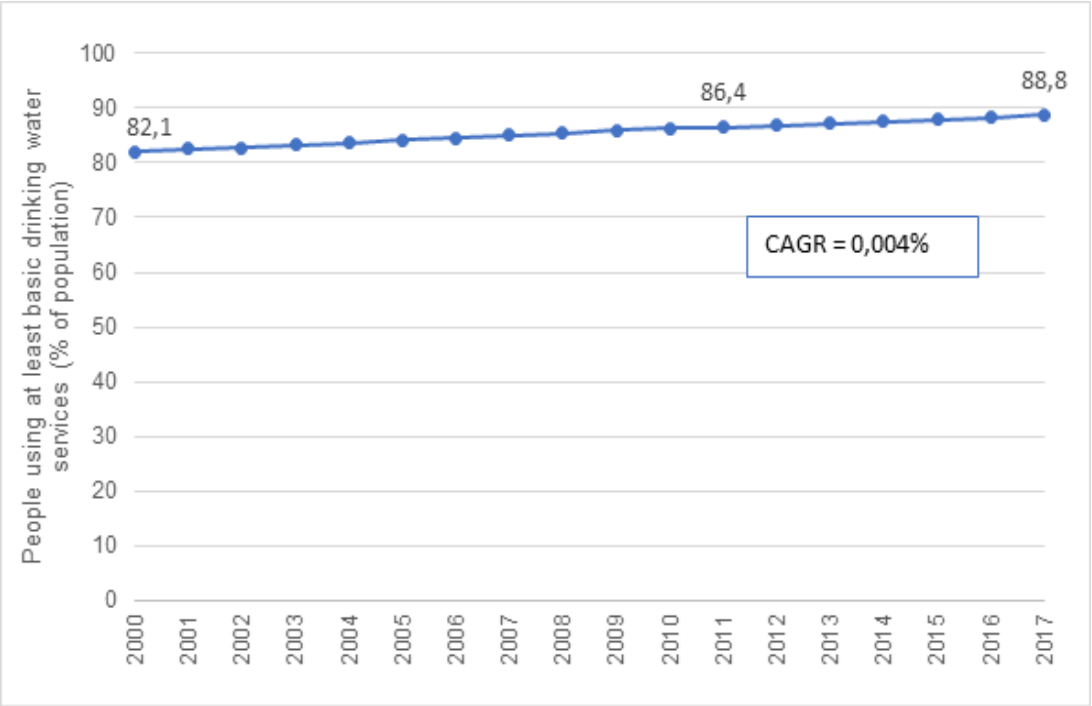

Figure 1.53. People using at least basic drinking water services, South Africa

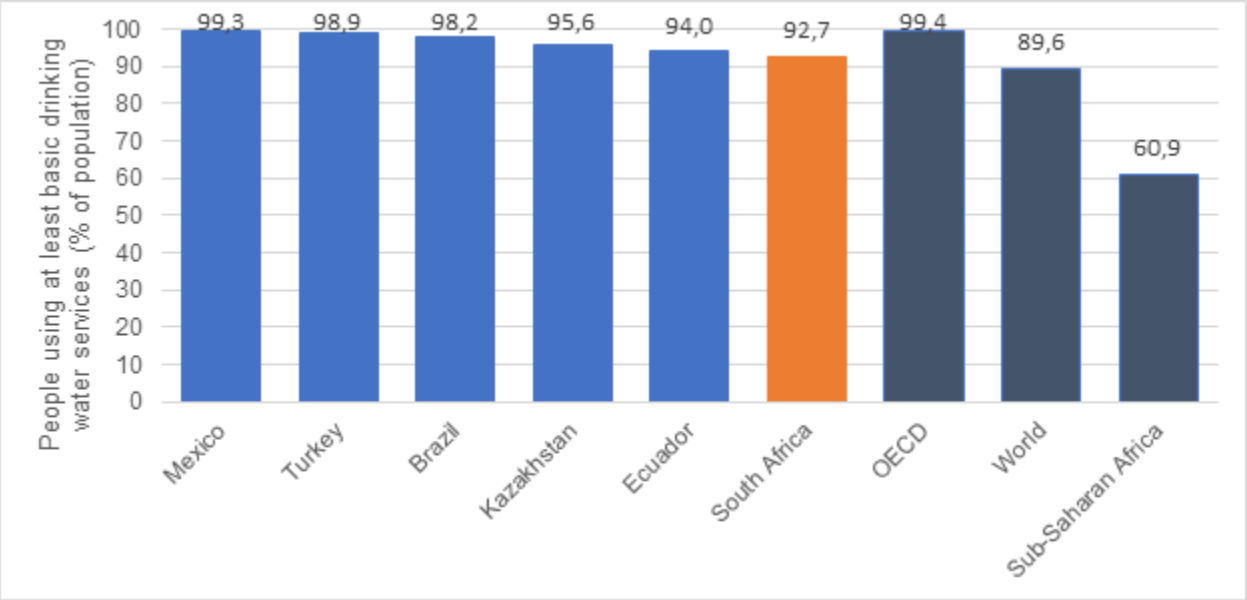

Figure 1.54. People using at least basic drinking water services, 2017

1.5.2 People using at least basic drinking water services, rural (% of rural population)

The percentage of people using at least basic water services. This indicator encompasses both people using basic water services as well as those using safely managed water services. Basic drinking water services is defined as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.

Data on drinking water, sanitation and hygiene are produced by the Joint Monitoring Programme of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) based on administrative sources, national censuses, and nationally representative household surveys. WHO/UNICEF defines a basic drinking water service as drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip. Improved water sources include piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.

Access to water services in rural areas is relatively lower compared to urban areas. In South Africa, approximately 80 per cent of the rural population has access to clean water services (Figure 1.55). This figure is again much higher compared to the other Sub-Saharan African countries, but is still behind the other benchmark countries (Figure 1.56).

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org).

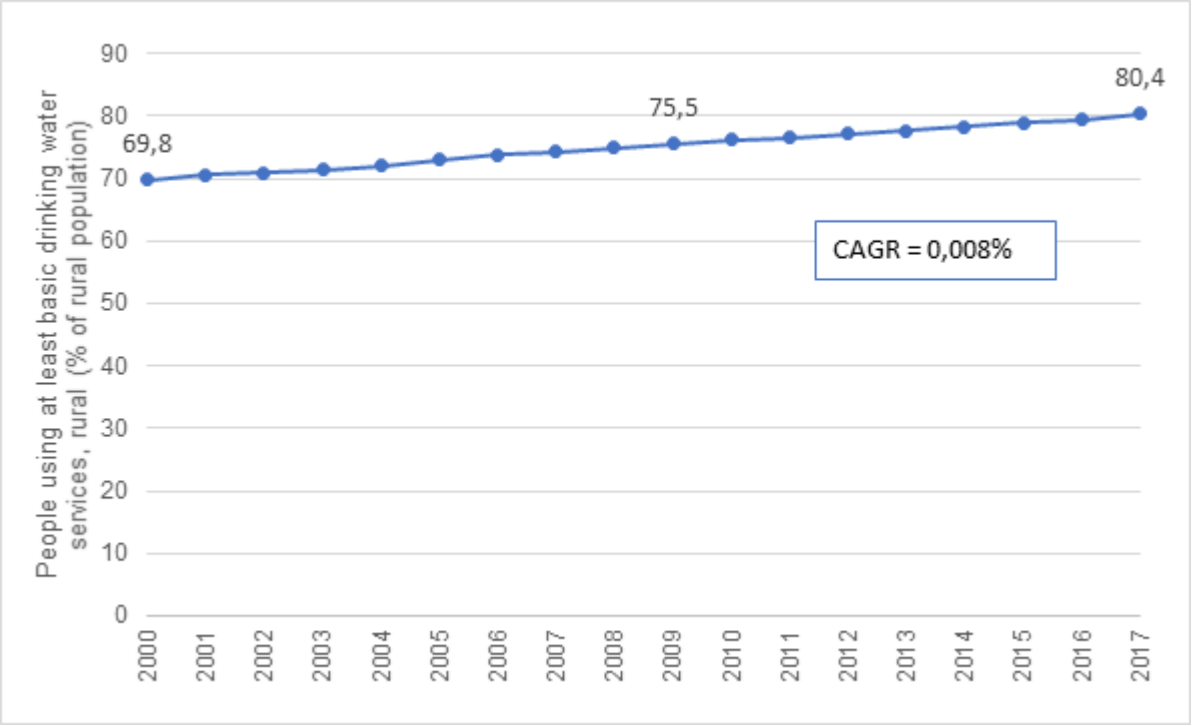

Figure 1.55. People using at least basic drinking water services, rural areas of South Africa

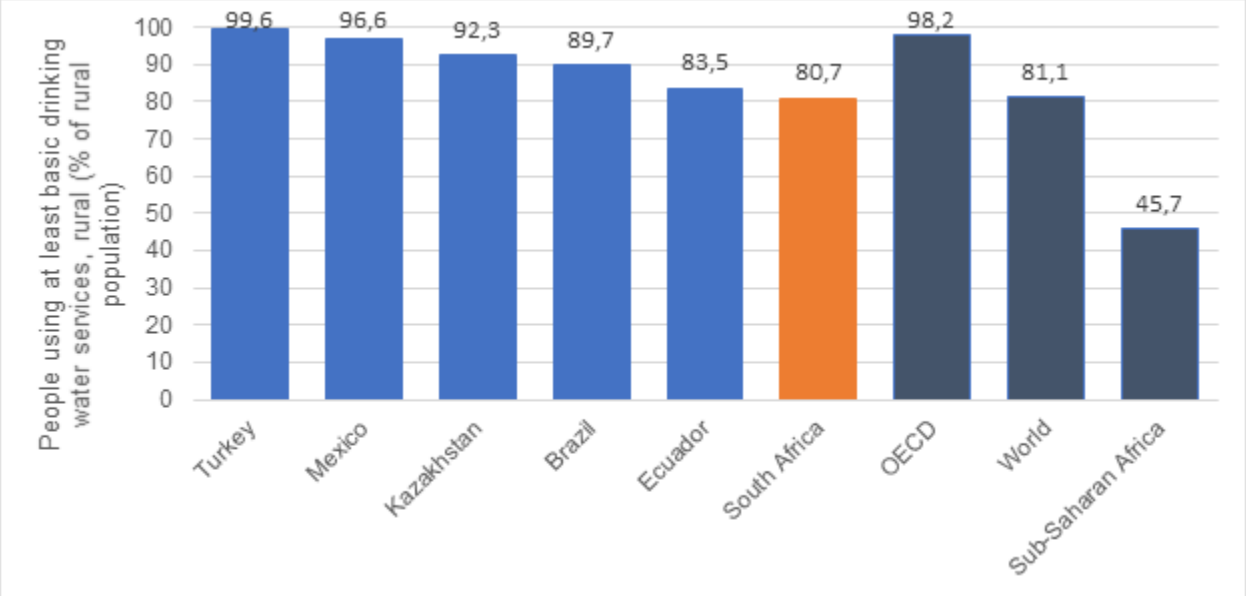

Figure 1.56. People using at least basic drinking water services, rural, 2017

1.5.3 People with basic handwashing facilities including soap and water (% of population)

The percentage of people living in households that have a handwashing facility with soap and water available on the premises. Handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing.

Soap includes bar soap, liquid soap, powder detergent, and soapy water but does not include ash, soil, sand, or other handwashing agents.

Data on drinking water, sanitation and hygiene are produced by the Joint Monitoring Programme of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) based on administrative sources, national censuses, and nationally representative household surveys. WHO/UNICEF defines a basic handwashing facility as a device to contain, transport or regulate the flow of water to facilitate handwashing with soap and water in the household.

The availability of basic handwashing functions in South African households is no more than 50% (Figure 1.57). This creates serious sanitation issues, especially considering the ongoing COVID-19 pandemic, for which water and soap are essential not to spread the virus. With these figures South Africa is well behind other benchmark countries (Figure 1.58). This is one of the areas where immediate action is required.

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org).

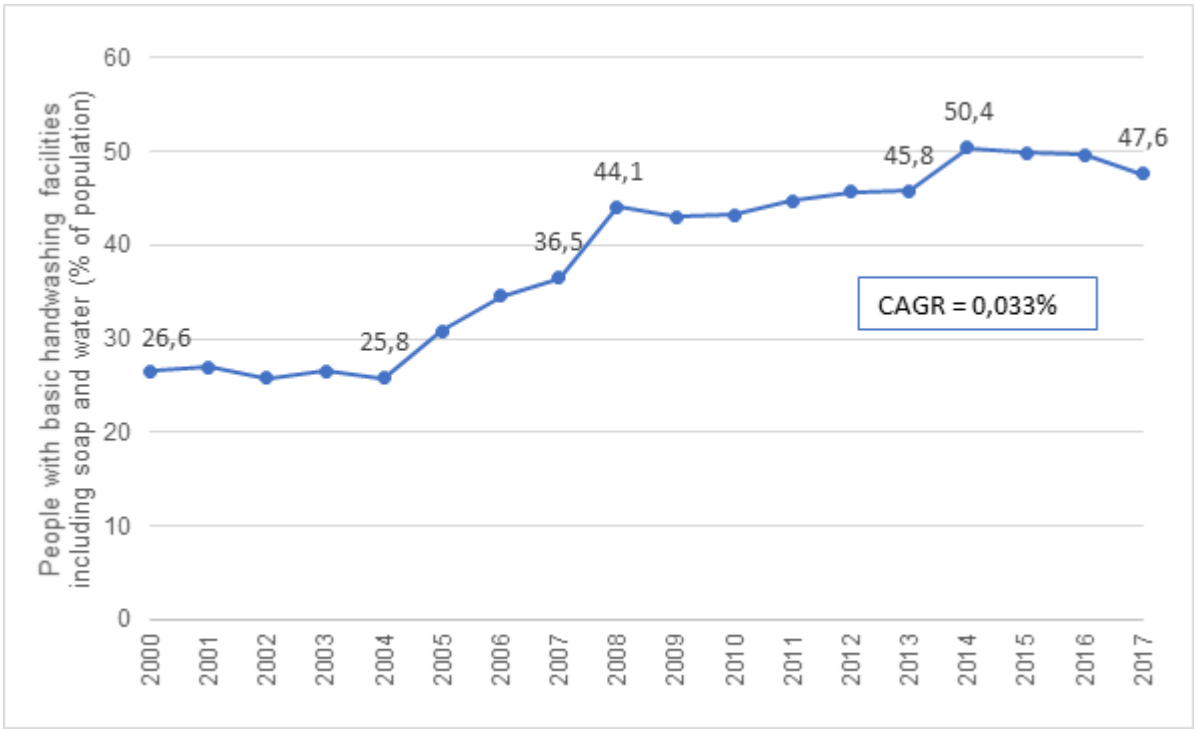

Figure 1.57. People with basic handwashing facilities including soap and water, South Africa

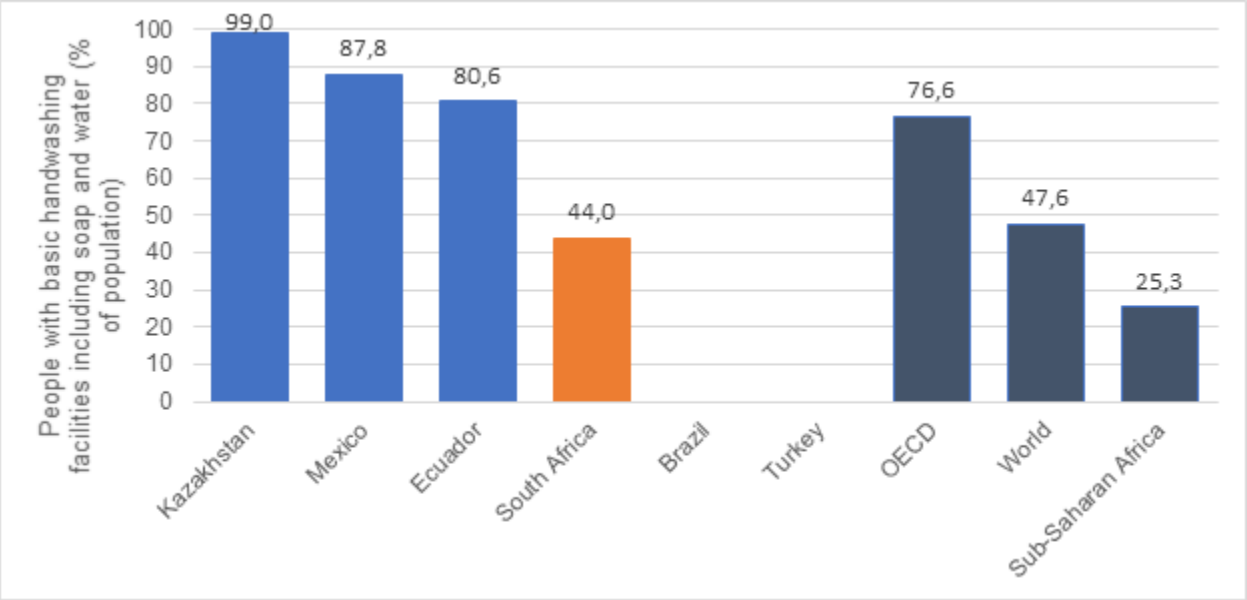

Figure 1.58. People with basic handwashing facilities including soap and water, 2017

1.5.4 People with basic handwashing facilities including soap and water, rural (% of rural population)

The percentage of people living in households that have a handwashing facility with soap and water available on the premises. Handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing. Soap includes bar soap, liquid soap, powder detergent, and soapy water but does not include ash, soil, sand, or other handwashing agents.

Data on drinking water, sanitation and hygiene are produced by the Joint Monitoring Programme of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) based on administrative sources, national censuses, and nationally representative household surveys. WHO/UNICEF defines a basic handwashing facility as a device to contain, transport or regulate the flow of water to facilitate handwashing with soap and water in the household.

Considering the rural areas, the situation is more dramatic in terms of accessing basic hygiene facilities. Only around 40 per cent of the rural population has access to soap and water (Figure 1.59). These figures are well behind the other countries for comparison as well the OECD and the World average (Figure 1.60).

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org).

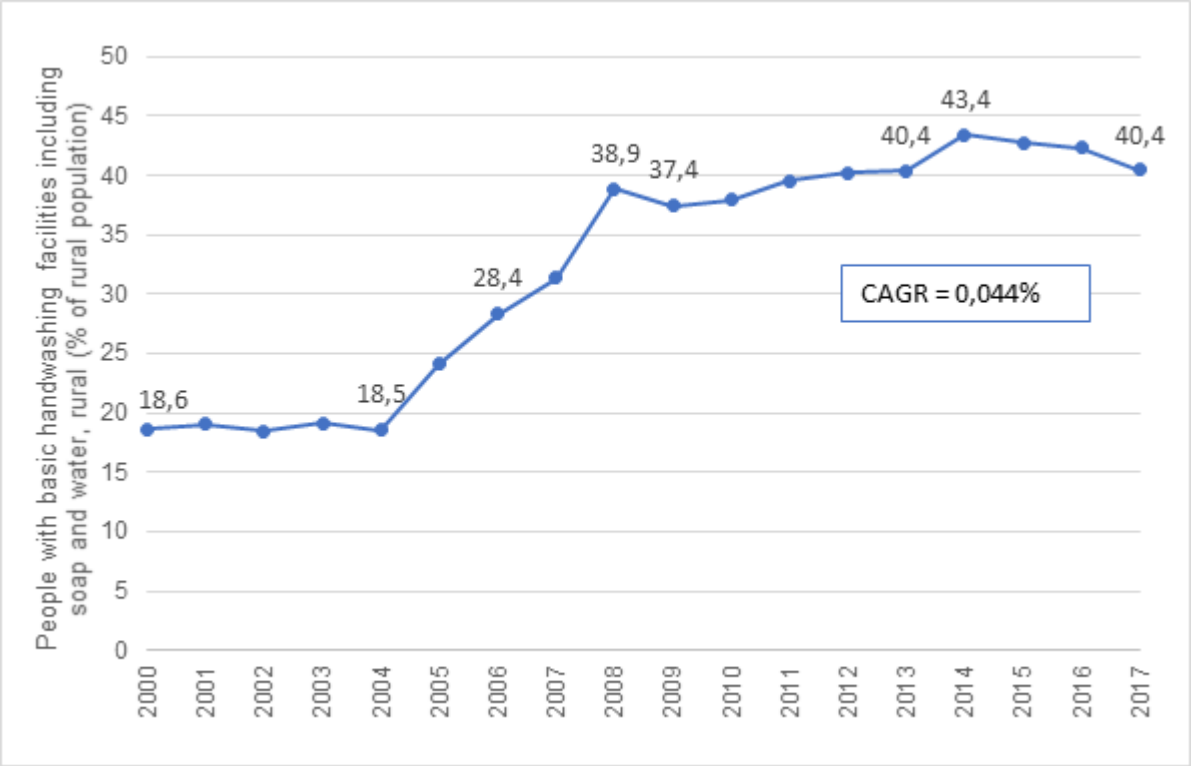

Figure 1.59. People with basic handwashing facilities including soap and water, rural, South Africa

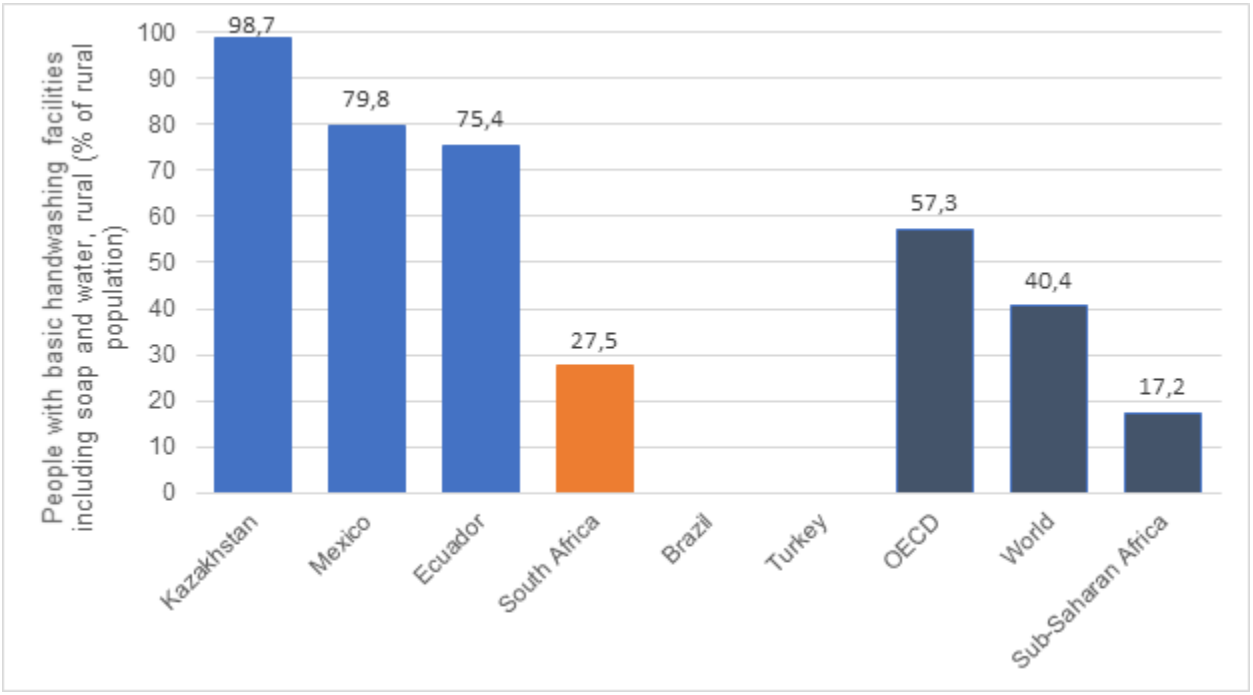

Figure 1.60. People with basic handwashing facilities including soap and water (rural), 2017

1.5.5 People with basic handwashing facilities including soap and water, urban (% of urban population)

The percentage of people living in households that have a handwashing facility with soap and water available on the premises. Handwashing facilities may be fixed or mobile and include a sink with tap water, buckets with taps, tippy-taps, and jugs or basins designated for handwashing. Soap includes bar soap, liquid soap, powder detergent, and soapy water but does not include ash, soil, sand, or other handwashing agents.

Data on drinking water, sanitation and hygiene are produced by the Joint Monitoring Programme of the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) based on administrative sources, national censuses, and nationally representative household surveys. WHO/UNICEF defines a basic handwashing facility as a device to contain, transport or regulate the flow of water to facilitate handwashing with soap and water in the household.

Urban population of South Africa is relatively better positioned compared to the rural populations in terms of availability of basic handwashing facilities with 56.2 per cent in 2017 (Figure 1.61). However, this is still very low compared to other benchmark countries, and below the World average, which is also very low (Figure 1.62).

Source: WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene (washdata.org).

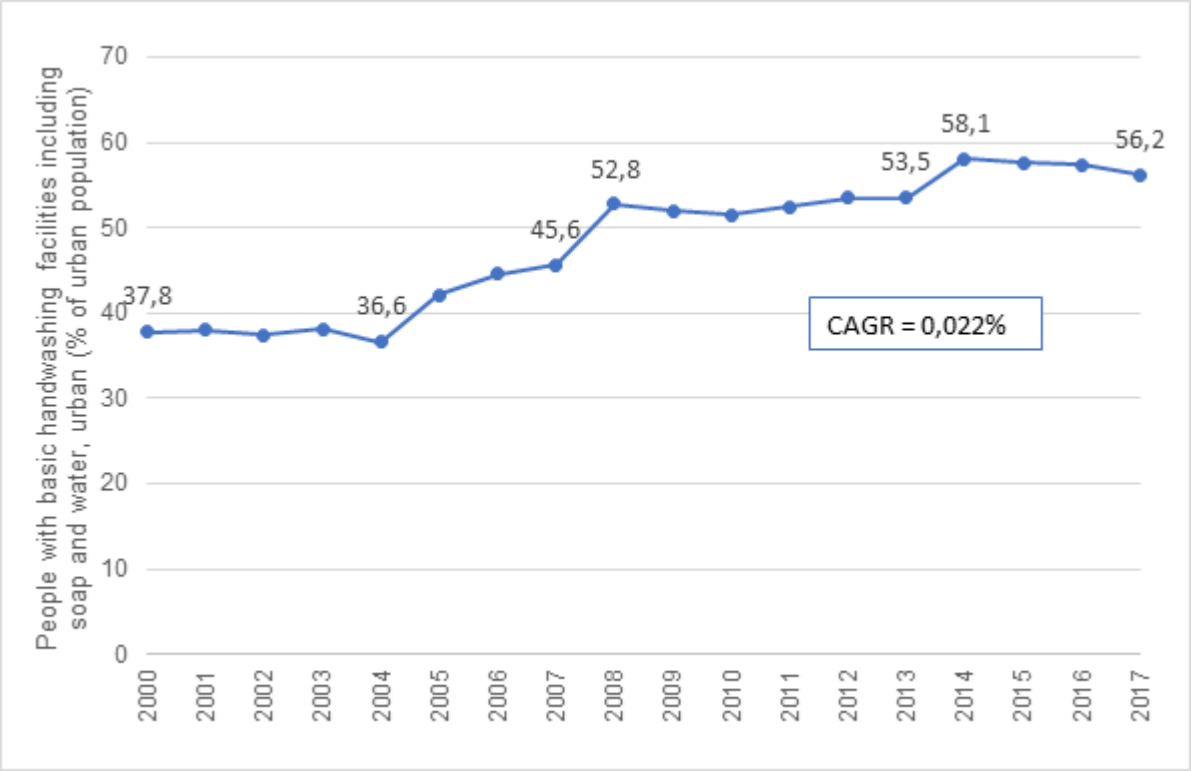

Figure 1.61. People with basic handwashing facilities including soap and water (urban), South Africa

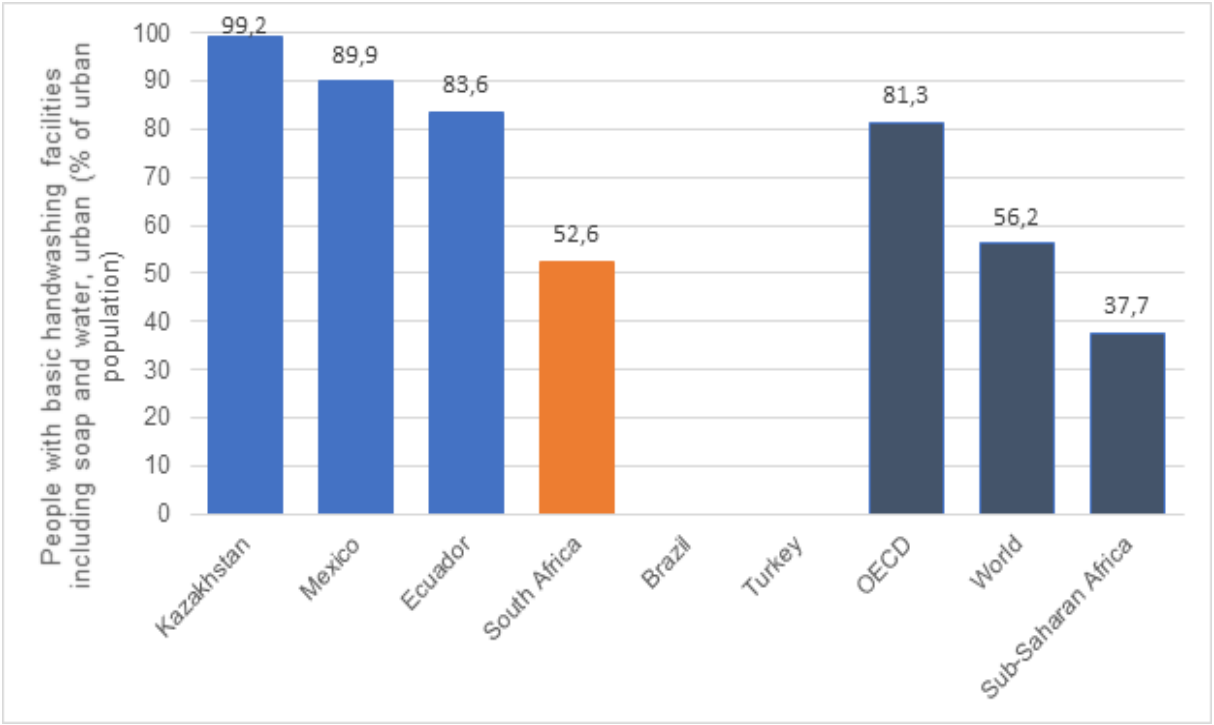

Figure 1.62. People with basic handwashing facilities including soap and water (urban), 2017

1.5.6 Normalized indicators values and composite index for the «Access and supply of clean water» factor

Figure 1.63 illustrate that South Africa is relatively better positioned in terms of accessing basic drinking water and well behind in terms of the availability of basic handwashing facilities. The overall performance of the country in access and supply of clean water is just above average.

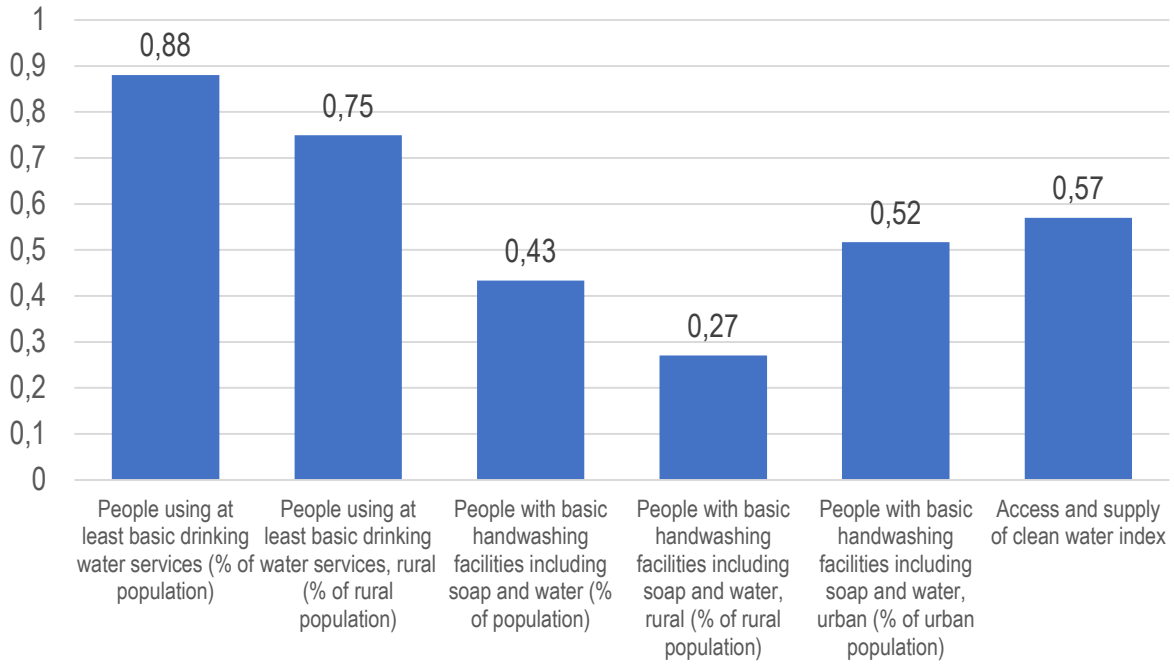

Figure 1.63. Normalized indicators values and a composite index for the «Access and supply of clean water» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.6 Job creation

1.6.1 Labor force participation rate, total (% of total population ages 15+) (modeled ILO estimate)

Labor force participation rate is the proportion of the population ages 15 and older that is economically active: all people who supply labor to produce goods and services during a specified period.

The labor force is the supply of labor available for producing goods and services in an economy. It includes people who are currently employed and people who are unemployed but

seeking work as well as first-time jobseekers. Not everyone who works is included, however. Unpaid workers, family workers, and students are often omitted, and some countries do not count members of the armed forces. Labor force size tends to vary during the year as seasonal workers enter and leave.

Unemployment is another major issue to be addressed for South Africa. Currently only around 56 per cent of the population is economically active participates in the production of goods and services. Unfortunately, this figure did not change much in the past two decades (Figure 1.64). As of 2019, labour force participation rate is only higher than Turkey and well behind other benchmark countries as well as the World and Sub-Saharan African countries average (Figure 1.65).

Source: International Labour Organization, ILOSTAT database. Data retrieved on September 20, 2020.

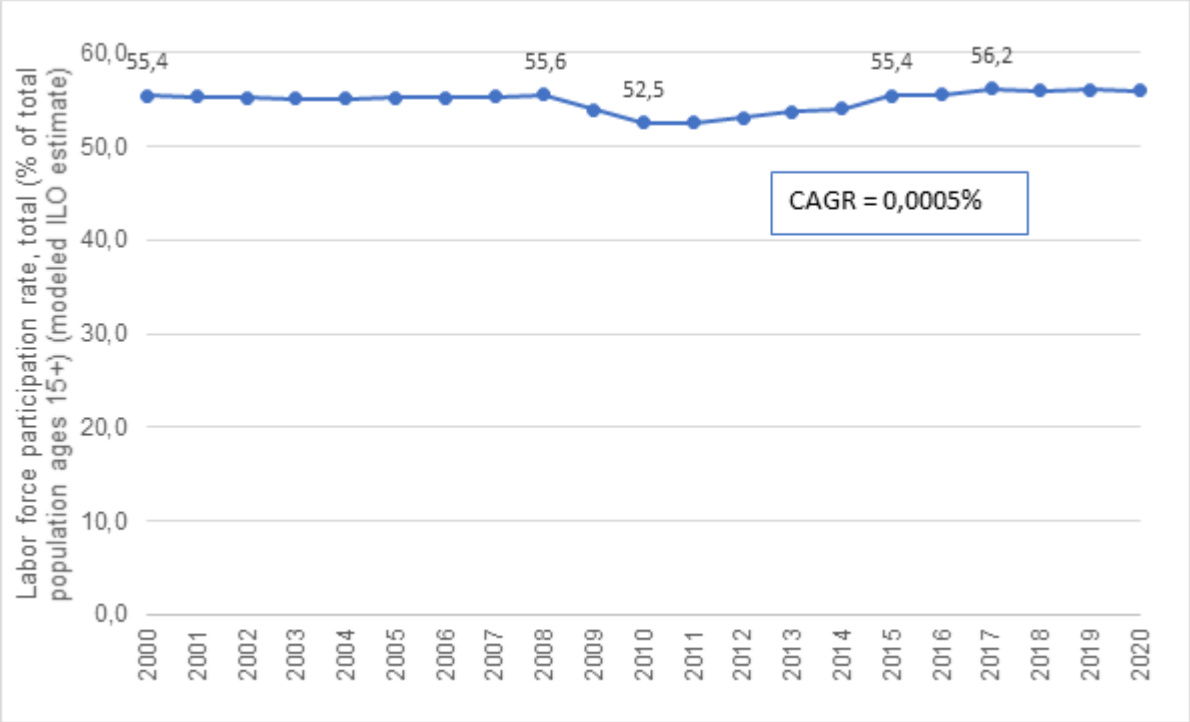

Figure 1.64. Labor force participation rate of South Africa

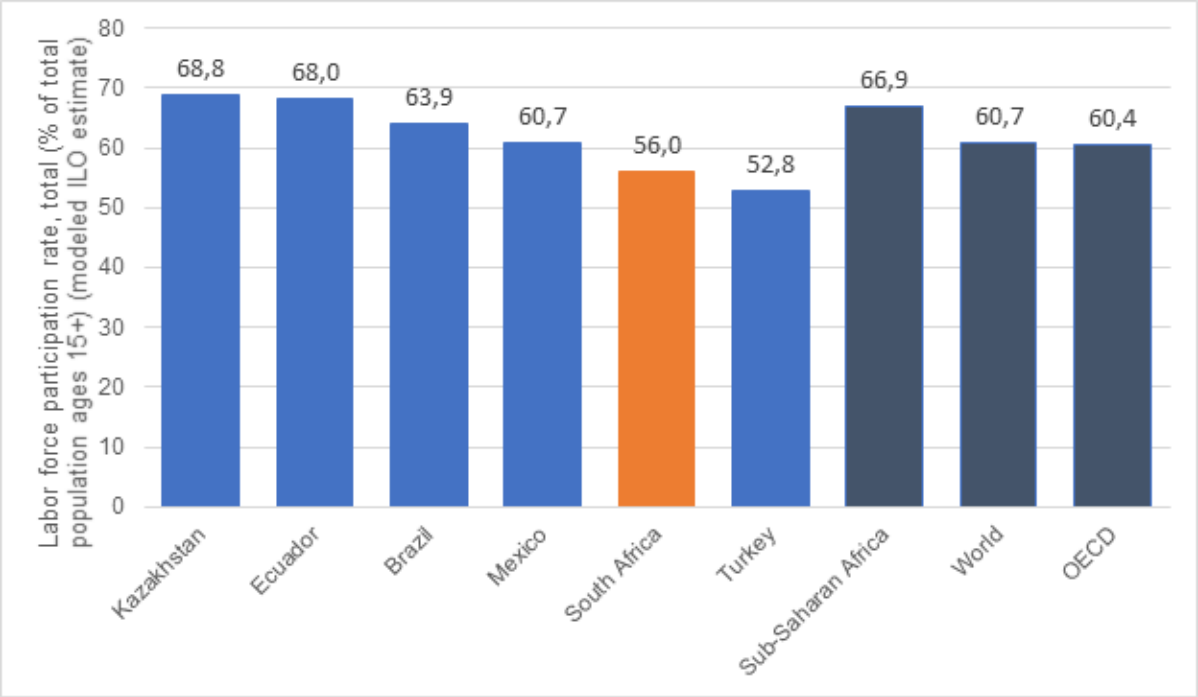

Figure 1.65. Labor force participation rate, 2019

1.6.2 Labor force with advanced education (% of total working-age population with advanced education)

The percentage of the working age population with an advanced level of education who are in the labor force. Advanced education comprises short-cycle tertiary education, a bachelor's degree or equivalent education level, a master's degree or equivalent education level, or doctoral degree or equivalent education level according to the International Standard Classification of Education 2011 (ISCED 2011).

Data suggests that labor force with higher education have better chance of employment in South Africa. As of 2017, 82 per cent of the working age population with advanced education participates in economically active working population (Figure 1.66). With this figure South Africa ranks the highest among the other benchmark countries, with higher figures then the averages of the OECD countries, the World and the Sub-Saharan African countries (Figure 1.67).

Source: International Labour Organization, ILOSTAT database. Data retrieved on September 20, 2020.

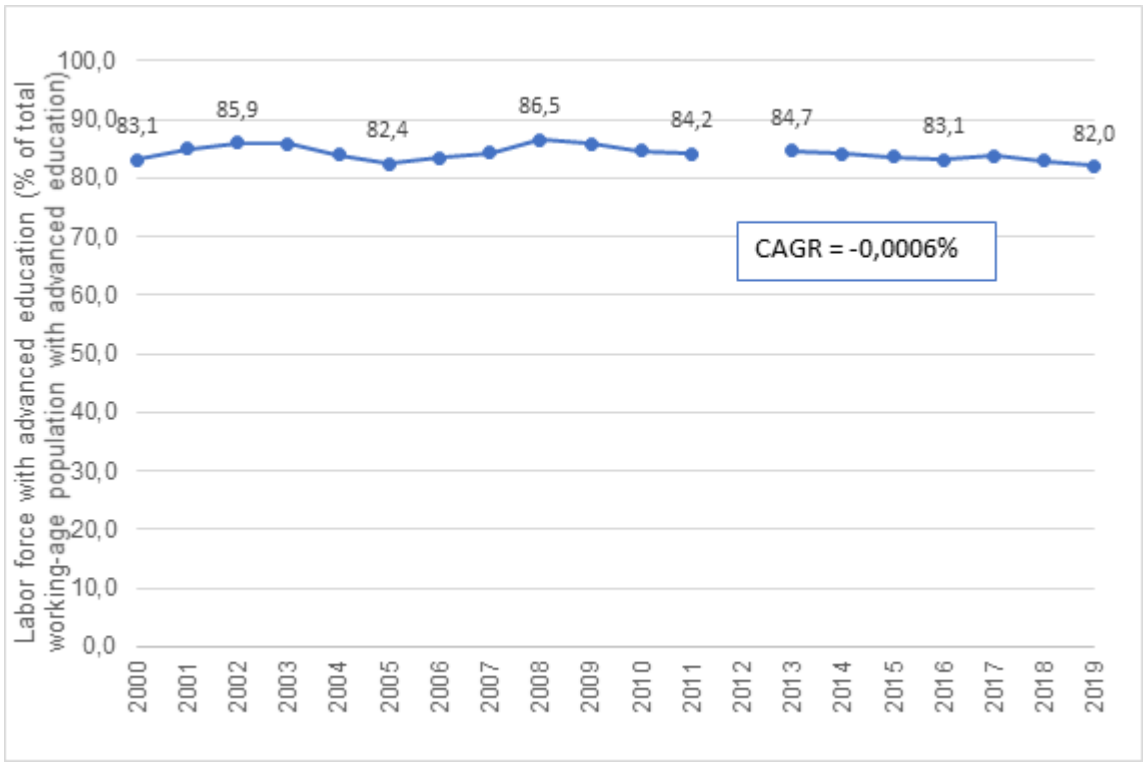

Figure 1.66. Labor force with advanced education of South Africa

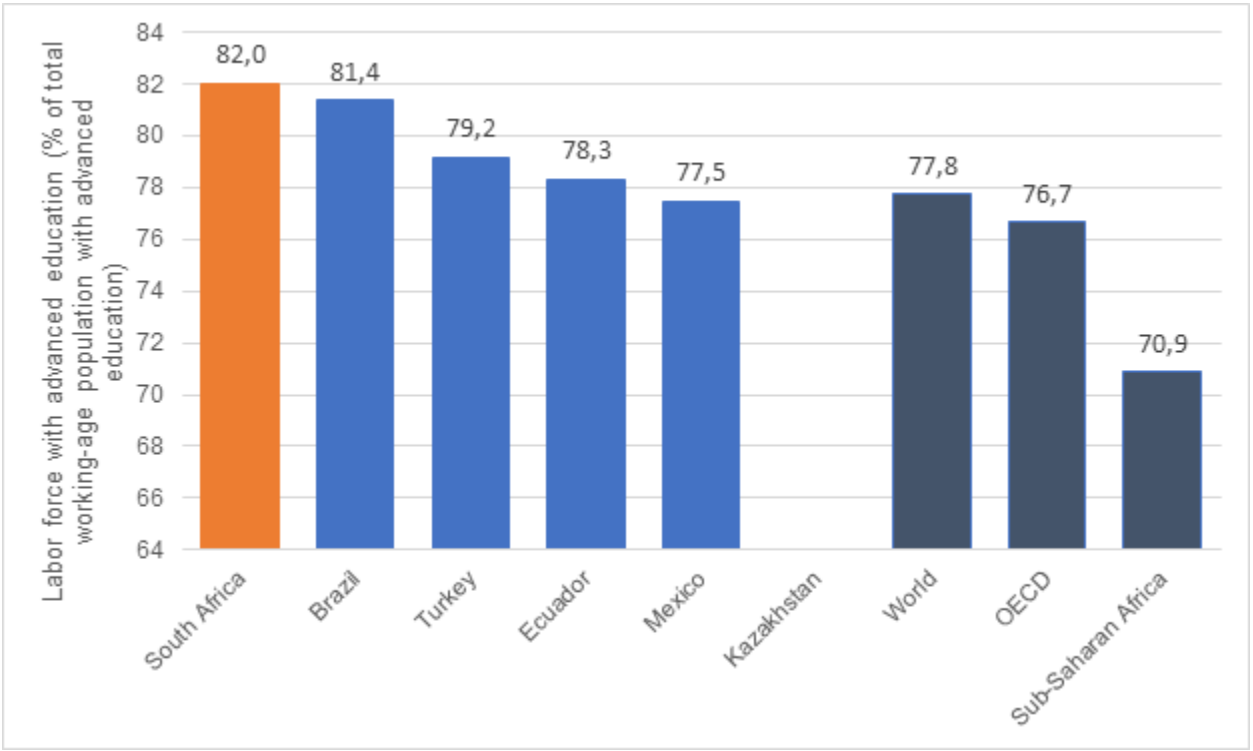

Figure 1.67. Labor force with advanced education, 2019

1.6.3 Unemployment with advanced education (% of total labor force with advanced education)

The percentage of the labor force with an advanced level of education who are unemployed. Advanced education comprises short-cycle tertiary education, a bachelor's degree or equivalent education level, a master's degree or equivalent education level, or doctoral degree or equivalent education level according to the International Standard Classification of Education 2011 (ISCED 2011).

Although employment rate of the population with advanced education has been high in South Africa, recent years indicate that unemployment of highly education people is in increase since the year 2007, reaching to 13.6 per cent in 2019 (Figure 1.68). Again with rate South Africa is ranking higher than the other countries in recent years (Figure 1.69).

Source: International Labour Organization, ILOSTAT database. Data retrieved on September 20, 2020.

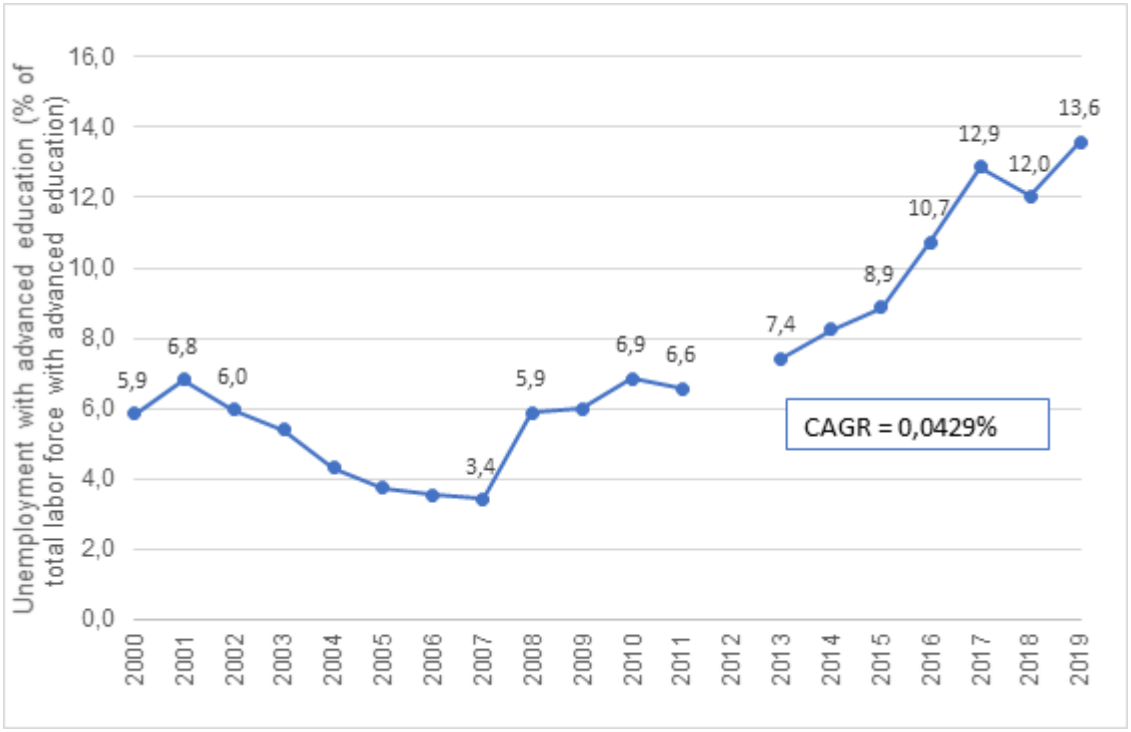

Figure 1.68. Unemployment with advanced education of South Africa

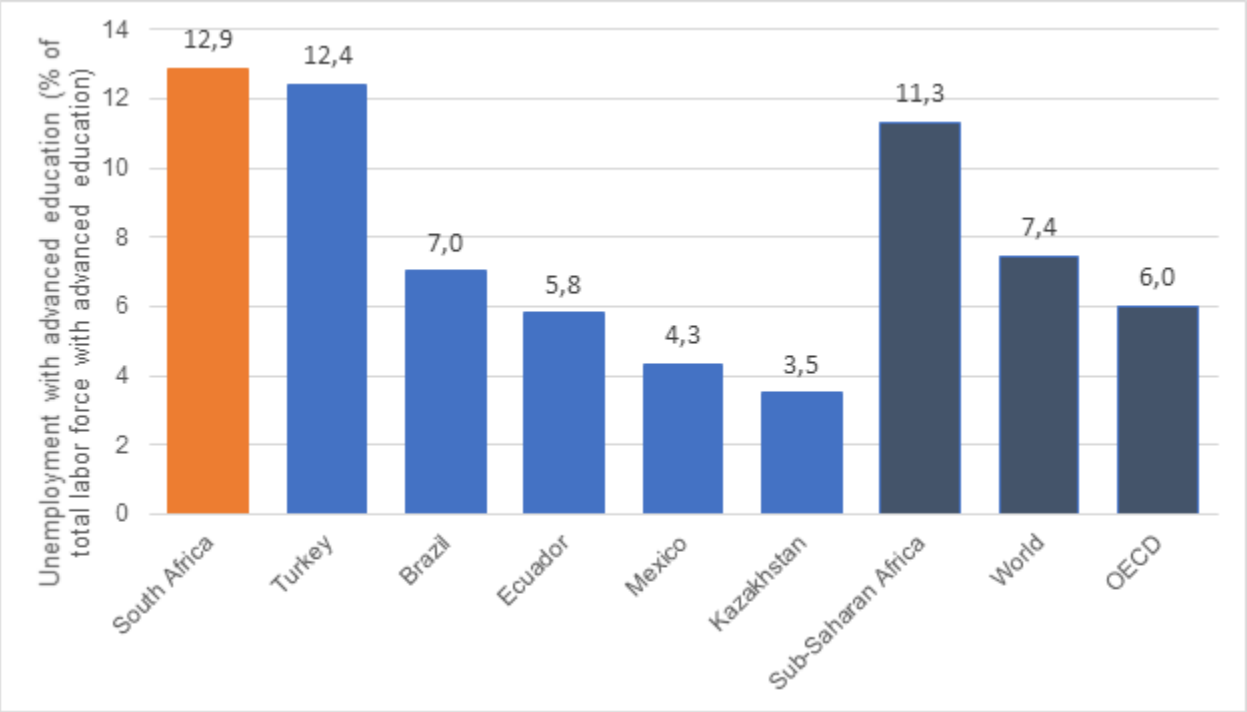

Figure 1.69. Unemployment with advanced education, 2017

1.6.4 Unemployment with basic education (% of total labor force with basic education)

The percentage of the labor force with a basic level of education who are unemployed. Basic education comprises primary education or lower secondary education according to the International Standard Classification of Education 2011 (ISCED 2011).

Unemployment of population with basic education in South Africa has been constantly above 30 per cent in the last twenty years (Figure 1.70). With these rates South Africa ranks the highest among the other countries (Figure 1.71).

Source: International Labour Organization, ILOSTAT database. Data retrieved on September 20, 2020.

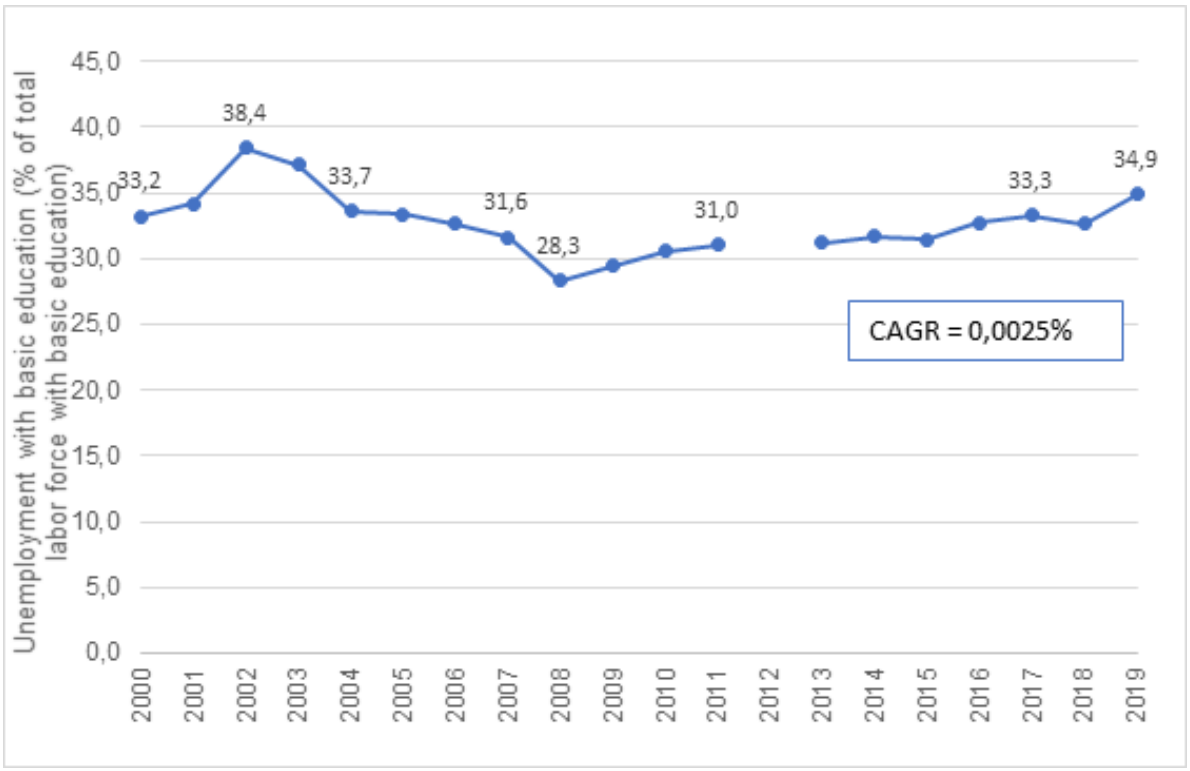

Figure 1.70. Unemployment with basic education of South Africa

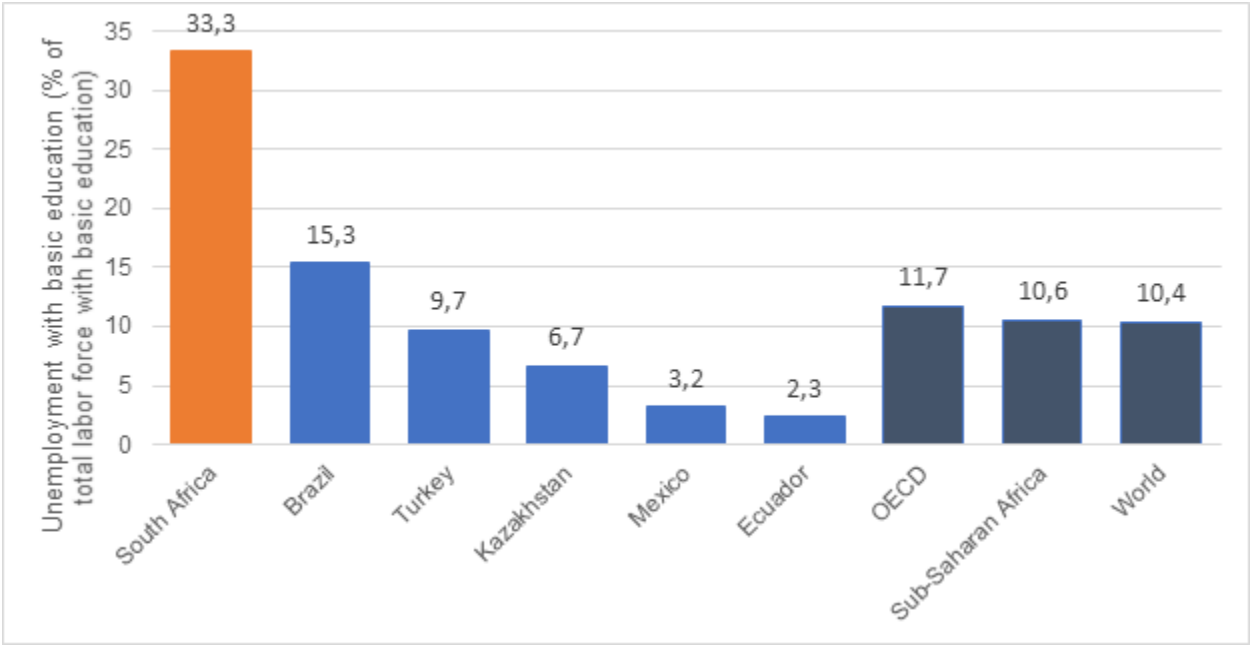

Figure 1.71. Unemployment with basic education, 2017

1.6.5 Unemployment with intermediate education (% of total labor force with intermediate education)

The percentage of the labor force with an intermediate level of education who are unemployed. Intermediate education comprises upper secondary or post-secondary non tertiary education according to the International Standard Classification of Education 2011 (ISCED 2011).

Similarly, unemployment rate is approximately 30 per cent in South Africa, and again this is much higher than the other countries (Figure 1.72 & 1.73).

Source: International Labour Organization, ILOSTAT database. Data retrieved on September 20, 2020.

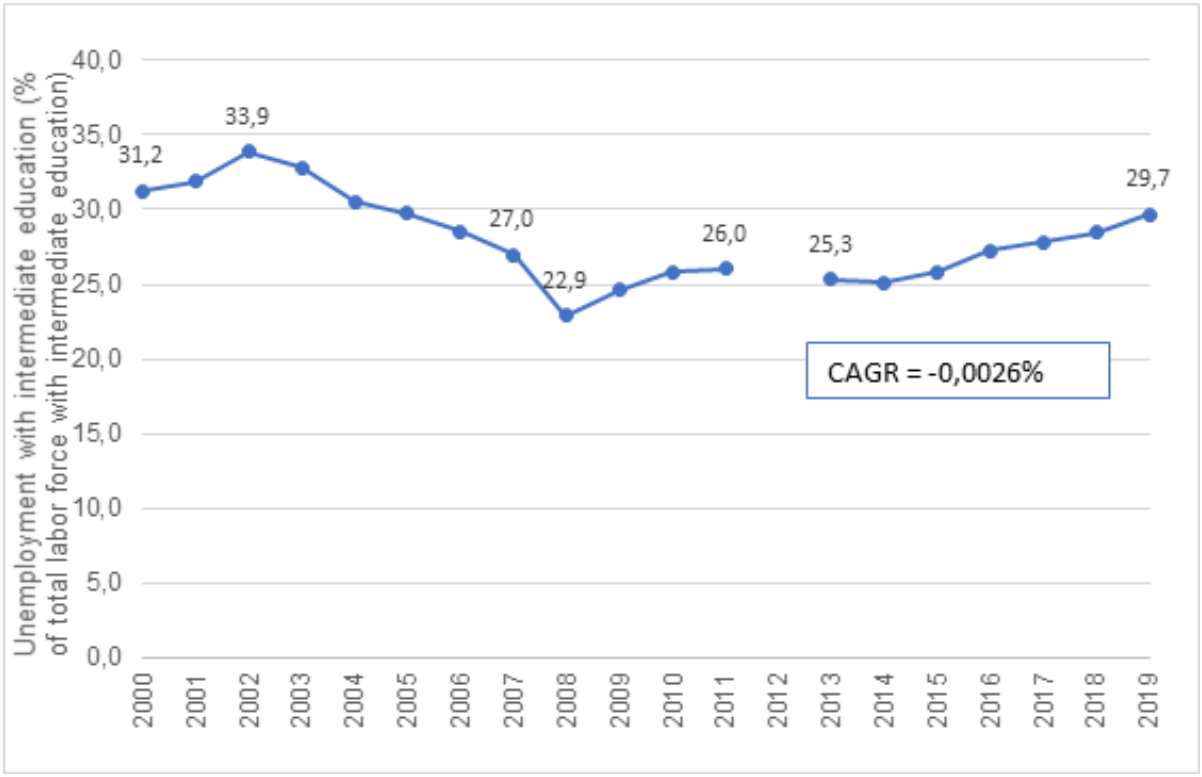

Figure 1.72. Unemployment with intermediate education of South Africa

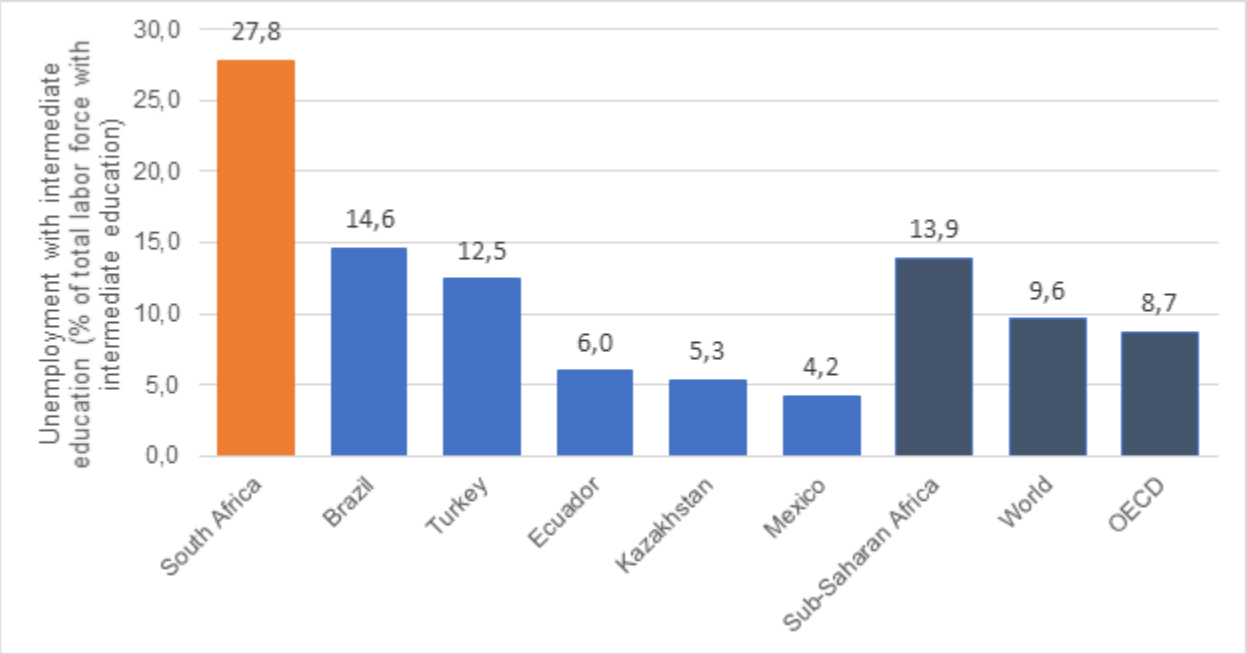

Figure 1.73. Unemployment with intermediate education, 2017

1.6.6 Normalized indicators values and composite index for the «Job creation» factor

The normalized indicators and composite index indicate that South Africa is relatively better positioned in the employment of population with advanced education. However in terms of overall job creation index, the country is behind the other benchmark countries (Figure 1.74).

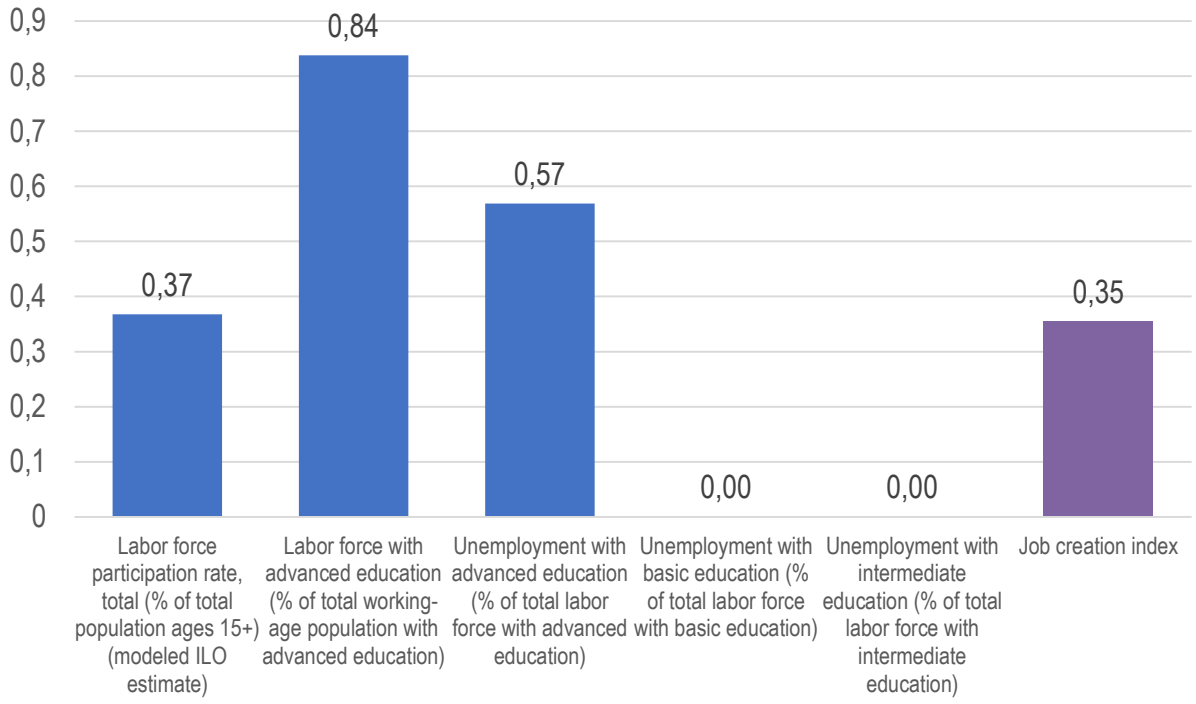

Figure 1.74. Normalized indicators values and a composite index for the «Job creation» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.7 Export growth and competitiveness

1.7.1 Cost of business start-up procedures (% of GNI per capita)

Cost to register a business is normalized by presenting it as a percentage of gross national income (GNI) per capita.

Data are collected by the World Bank with a standardized survey that uses a simple business case to ensure comparability across economies and over time - with assumptions about the legal form of the business, its size, its location, and nature of its operation. Surveys are administered through more than 9,000 local experts, including lawyers, business consultants, accountants, freight forwarders, government officials, and other professionals who routinely administer or advise on legal and regulatory requirements.

South Africa has been much business friendlier in recent years. The cost of registering a new business has substantially gone down from 9.4 per cent of GNI per capita in 2003 to 0.2 in 2019 (Figure 1.75). This much lower than the other benchmark countries and only equals the amount in Kazakhstan (Figure1.76).

Source: World Bank, Doing Business project (http://www.doingbusiness.org/).

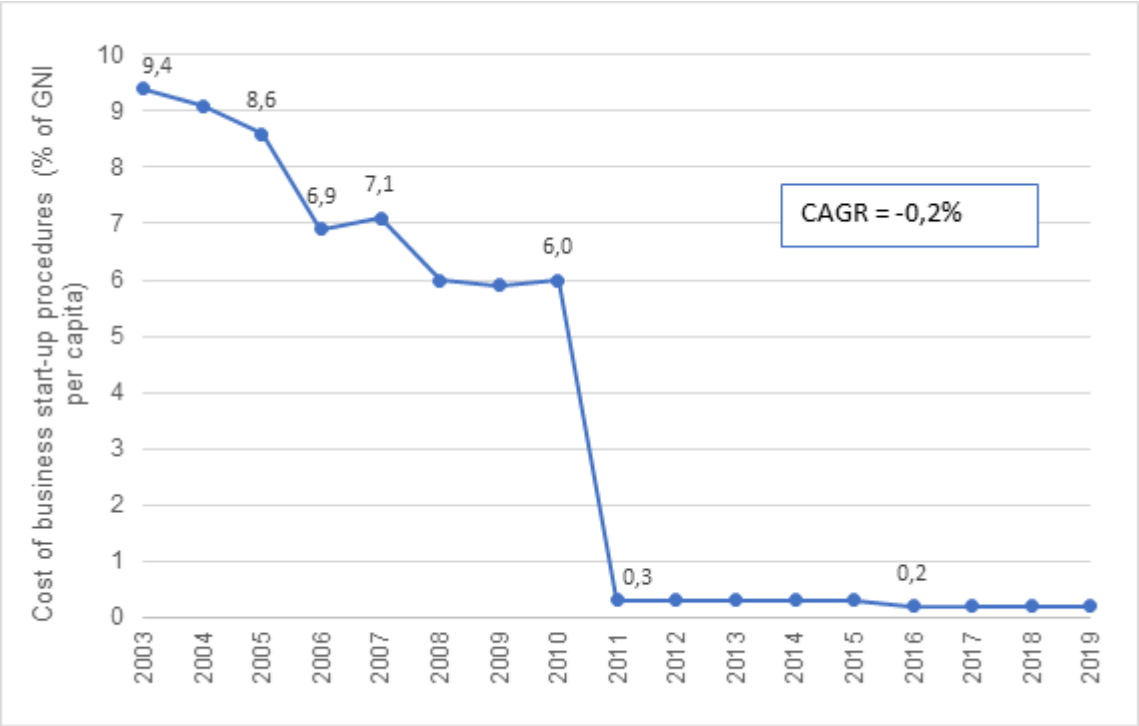

Figure 1.75. Cost of business start-up procedures in South Africa

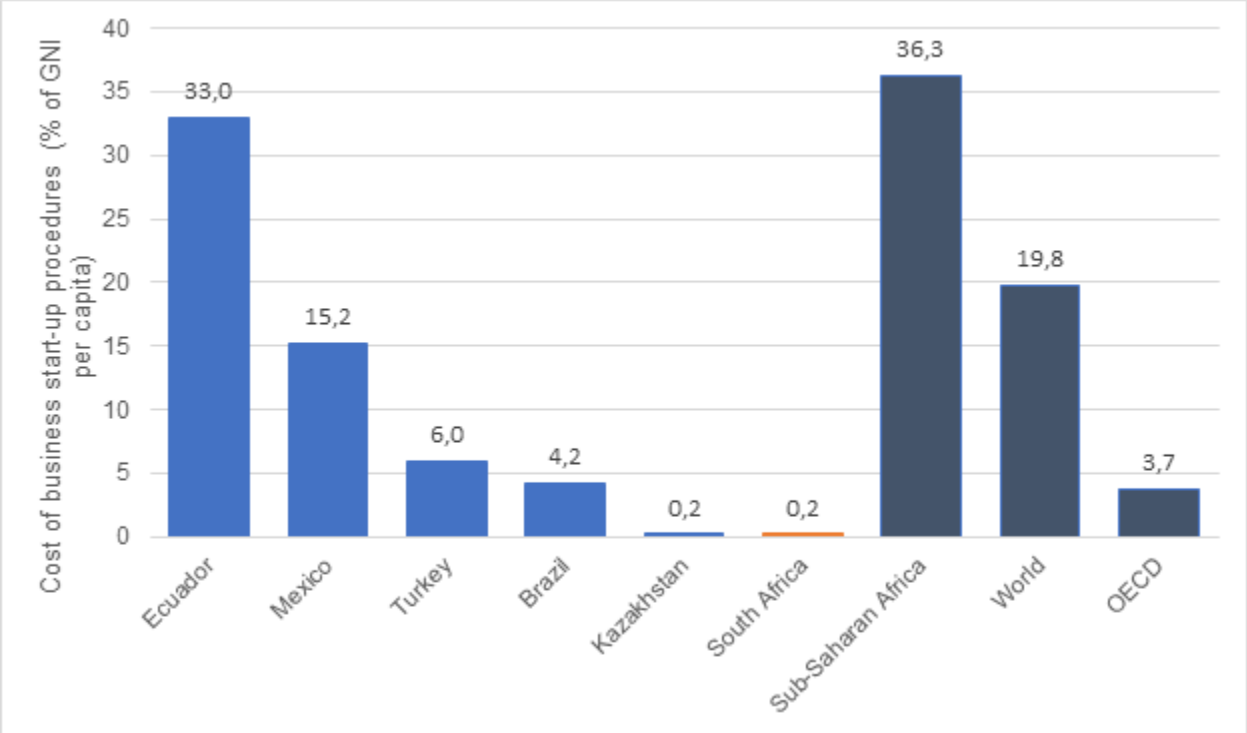

Figure 1.76. Cost of business start-up procedures, 2019

1.7.2 Ease of doing business score (0 = lowest performance to 100 = best performance)

In terms of the ease of doing business, South Africa shows above average performance of 67.02 per cent, and comparable to other developing countries in the same category (Figure 1.77 & 1.78).

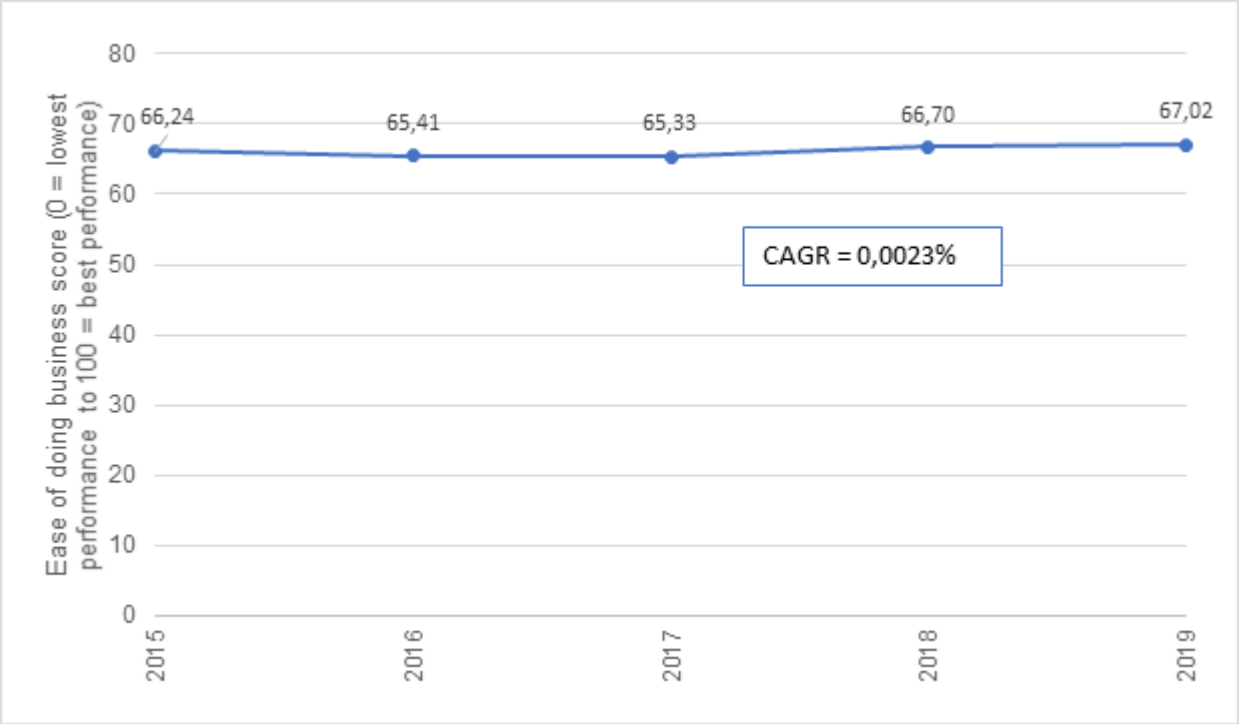

Figure 1.77. Ease of doing business score in South Africa

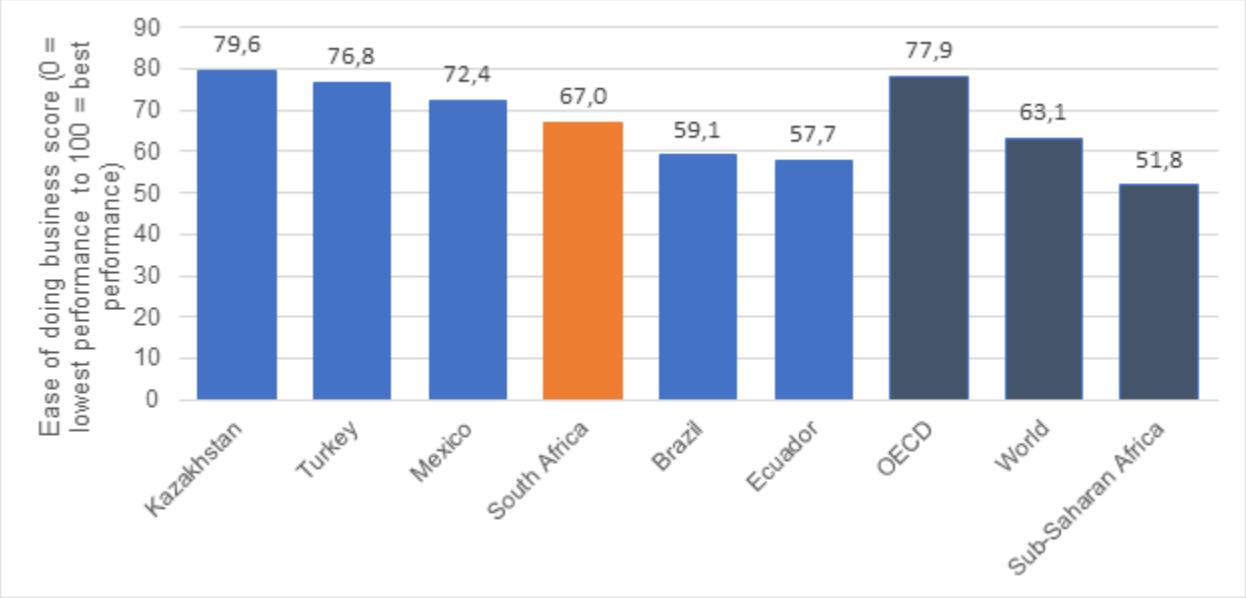

Figure 1.78. Ease of doing business score, 2019

1.7.3 Insurance and financial services (% of commercial service exports)

Insurance and financial services cover freight insurance on goods exported and other direct insurance such as life insurance; financial intermediation services such as commissions, foreign exchange transactions, and brokerage services; and auxiliary services such as financial market operational and regulatory services.

The balance of payments (BoP) is a double-entry accounting system that shows all flows of goods and services into and out of an economy; all transfers that are the counterpart of real resources or financial claims provided to or by the rest of the world without a quid pro quo, such as donations and grants; and all changes in residents' claims on and liabilities to nonresidents that arise from economic transactions. All transactions are recorded twice - once as a credit and once as a debit. In principle the net balance should be zero, but in practice the accounts often do not balance, requiring inclusion of a balancing item, net errors, and omissions.

The concepts and definitions underlying the data are based on the sixth edition of the International Monetary Fund's (IMF) Balance of Payments Manual (BPM6). Balance of payments data for 2005 onward will be presented in accord with the BPM6. The historical BPM5 data series will end with data for 2008, which can be accessed through the World Development Indicators archives.

The rate of insurance and financial services as percentage of commercial service exports has been relatively stable in South Africa after 2007 with around 7.6 per cent, and is only lower than Mexico among the benchmark countries (Figure 1.79 & 1.80).

Source: International Monetary Fund, Balance of Payments Statistics Yearbook, and data files.

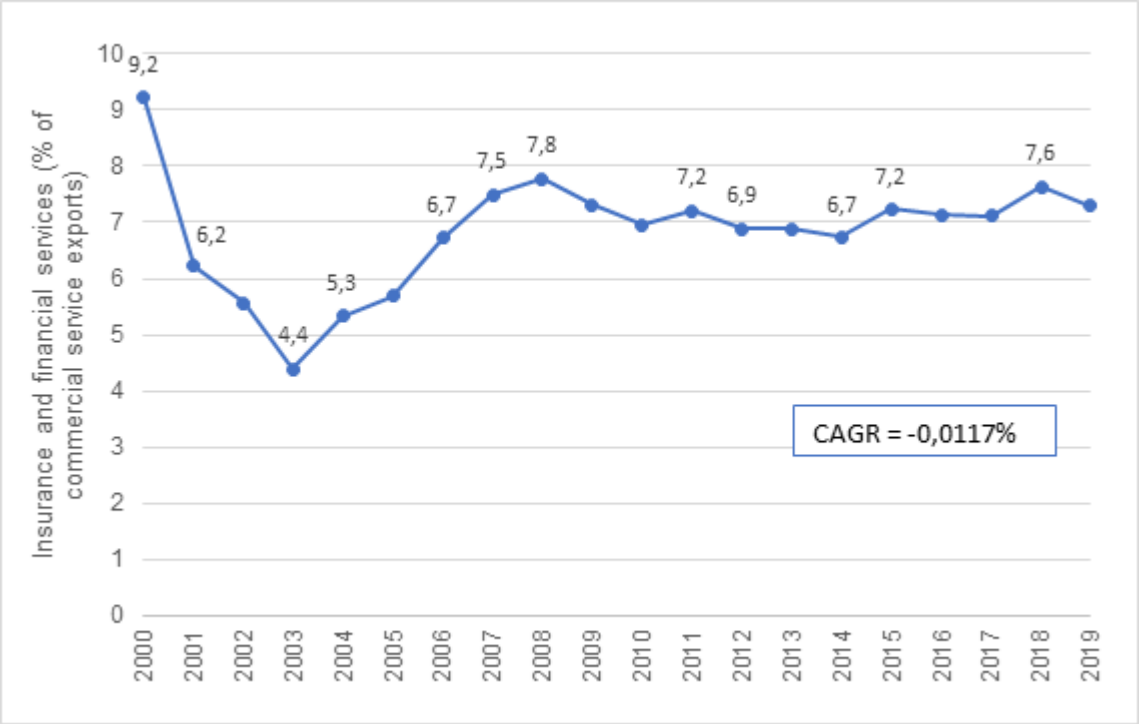

Figure 1.79. Insurance and financial services in South Africa

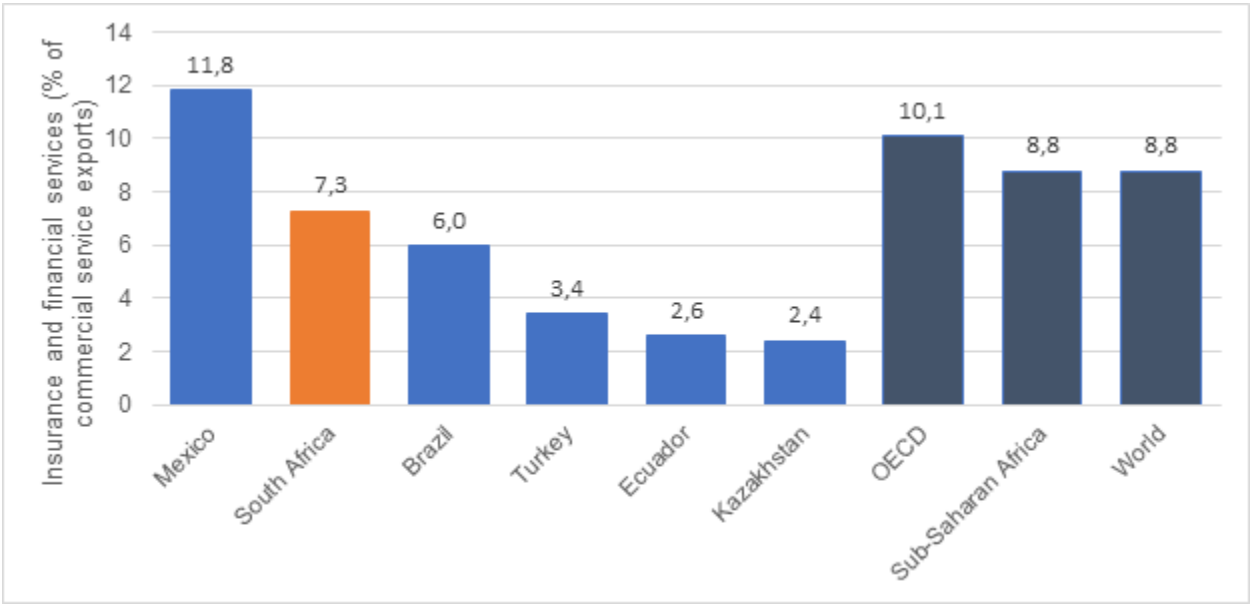

Figure 1.80. Insurance and financial services, 2019

1.7.4 Medium and high-tech exports (% manufactured exports)

Share of medium and high-tech manufactured exports in total manufactured exports.

The data from UN COMTRADE is downloaded in SITC Revision 3, 3-digit, by reporting country, year, partner code, commodity, and flow (export and re-export). SITC medium

technology: 266, 267, 512, 513, 533, 553, 554, 562, 571, 572, 573, 574, 575, 579, 581, 582, 583, 591, 593, 597, 598, 653, 671, 672, 678, 711, 712,713, 714, 721, 722, 723, 724, 725, 726, 727, 728, 731, 733, 735, 737, 741, 742, 743, 744, 745, 746, 747, 748, 749, 761, 762, 763, 772, 773, 775, 778, 781, 782, 783, 784, 785, 786, 791, 793, 811, 812, 813, 872, 873, 882, 884, 885; SITC high technology: 525, 541, 542, 716, 718, 751, 752, 759, 764, 771, 774, 776, 792, 871, 874, 881, 891. Net-exports are calculated as exports minus re-exports. Manufactured exports are the sum of the four categories resource-based exports, low-tech exports, medium tech exports and high-tech exports; and medium-high technology exports, is the sum of medium tech exports and high-tech exports. The world value of manufacturing exports is the sum of all manufacturing net exports.

South Africa's medium and high-tech exports remained stable in the range of 40 to 50 per cent in the last couple of decades. No real progress has been made towards the production and export of higher technology products and goods (Figure 1.81). Though the country is just second after Mexico and above the World averages with a close proximity to OECD average (Figure 1.82). This indicates that there are substantial progress has been made, but further advancements should be made in the decade to come.

Source: United Nations Industrial Development Organization (UNIDO), Competitive Industrial Performance (CIP) database

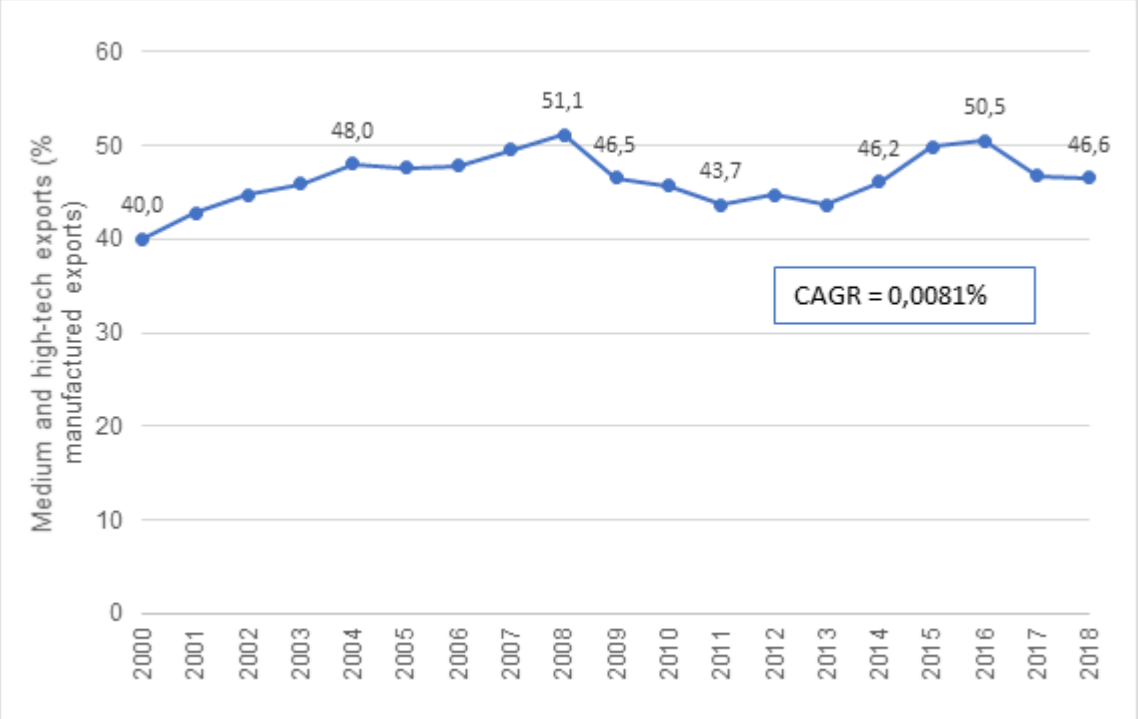

Figure 1.81. Medium and high-tech exports of South Africa

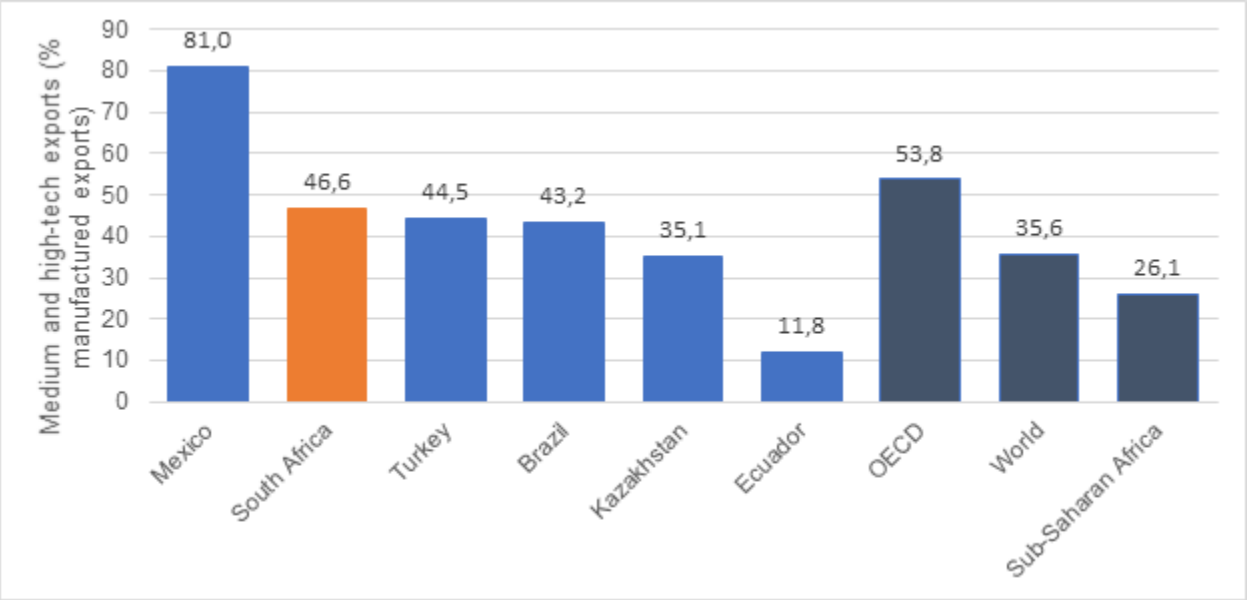

Figure 1.82. Medium and high-tech exports, 2018

1.7.5 Ores and metals exports (% of merchandise exports)

Ores and metals comprise the commodities in SITC sections 27 (crude fertilizer, minerals news); 28 (metalliferous ores, scrap); and 68 (non-ferrous metals).

The classification of commodity groups is based on the Standard International Trade Classification (SITC) revision 3.

South Africa still remains as a country relying on the exports of commodities. The share of ore and metal export has reached nearly to 30 per cent in 2019 (Figure 1.83). With this high rate of commodity exports, South Africa is the leader among the benchmark countries with higher rates than the OECD, the World and Sub-Saharan Africa averages (Figure 1.84).

Source: World Bank staff estimates through the WITS platform from the Comtrade database maintained by the United Nations Statistics Division.

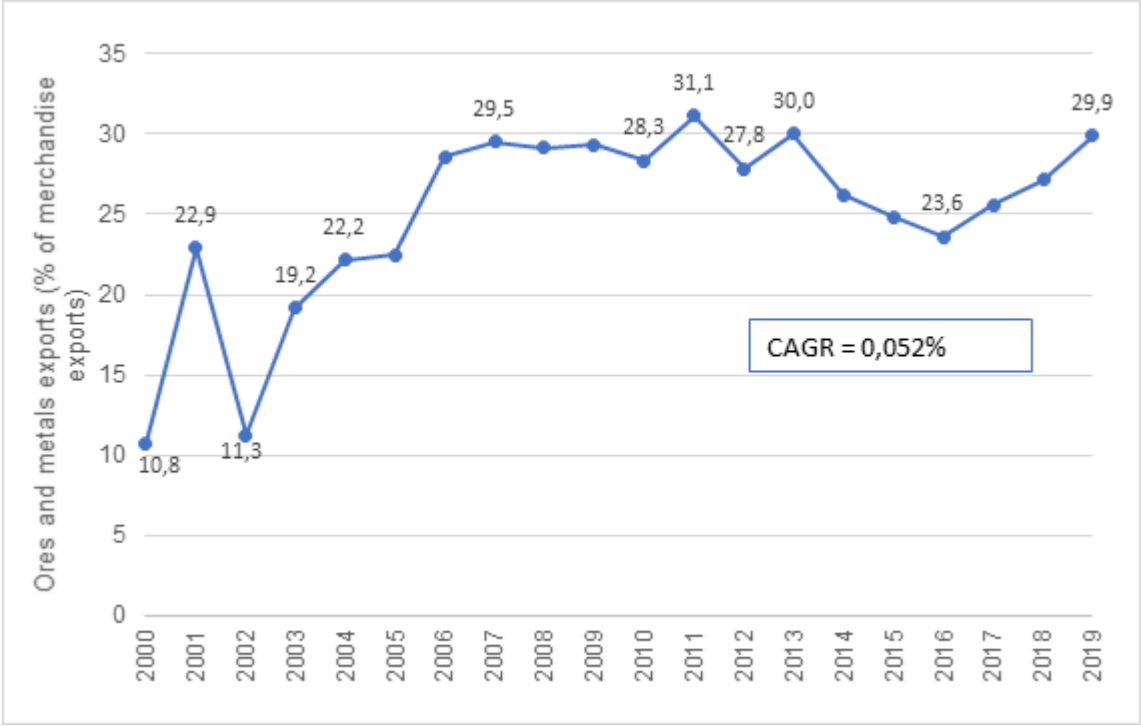

Figure 1.83. Ores and metals exports of South Africa

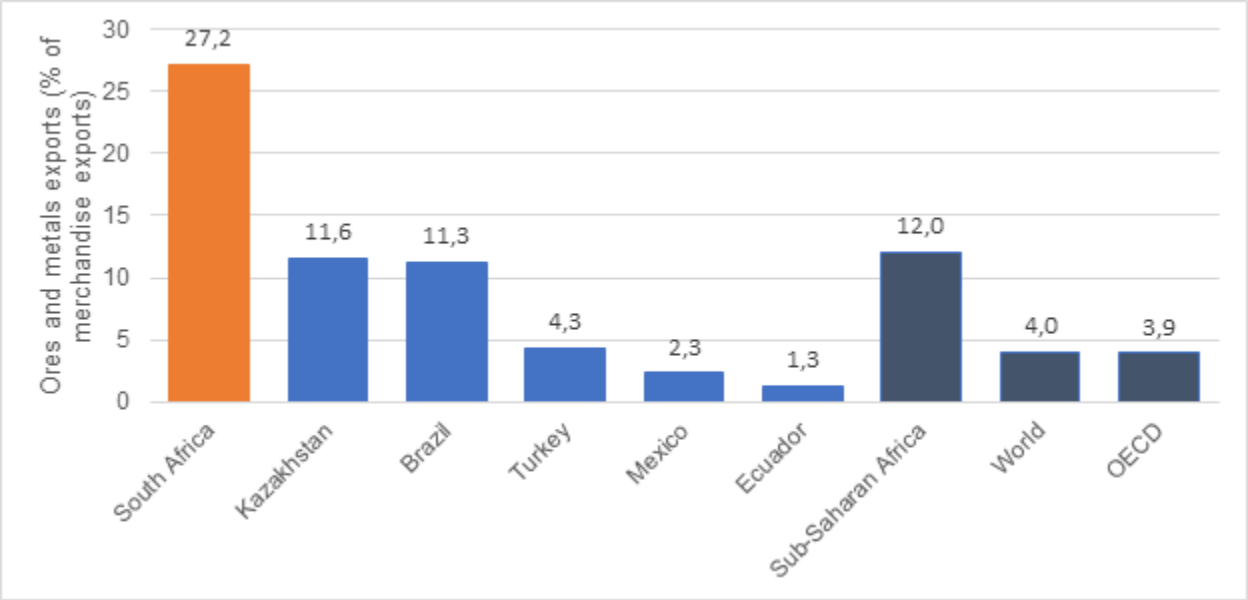

Figure 1.84. Ores and metals exports, 2018

1.7.6 Transport services (% of commercial service exports)

Transport services (% of commercial service exports) covers all transport services (sea, air, land, internal waterway, space, and pipeline) performed by residents of one economy for those of another and involving the carriage of passengers, movement of goods (freight), rental of carriers with crew, and related support and auxiliary services. Excluded are freight insurance, which is

included in insurance services; goods procured in ports by nonresident carriers and repairs of transport equipment, which are included in goods; repairs of railway facilities, harbors, and airfield facilities, which are included in construction services; and rental of carriers without crew, which is included in other services.

The balance of payments (BoP) is a double-entry accounting system that shows all flows of goods and services into and out of an economy; all transfers that are the counterpart of real resources or financial claims provided to or by the rest of the world without a quid pro quo, such as donations and grants; and all changes in residents' claims on and liabilities to nonresidents that arise from economic transactions. All transactions are recorded twice - once as a credit and once as a debit. In principle the net balance should be zero, but in practice the accounts often do not balance, requiring inclusion of a balancing item, net errors, and omissions.

The concepts and definitions underlying the data are based on the sixth edition of the International Monetary Fund's (IMF) Balance of Payments Manual (BPM6). Balance of payments data for 2005 onward will be presented in accordance with the BPM6. The historical BPM5 data series will end with data for 2008, which can be accessed through the World Development Indicators archives.

Despite of high export rates, the share of the country’s transport services as percentage of total commercial service exports has been declining continuously since the year 2000 (Figure 1.85). With these figures South Africa ranks behind most of the other benchmark countries except Mexico (Figure 1.86).

Source: International Monetary Fund, Balance of Payments Statistics Yearbook, and data files.

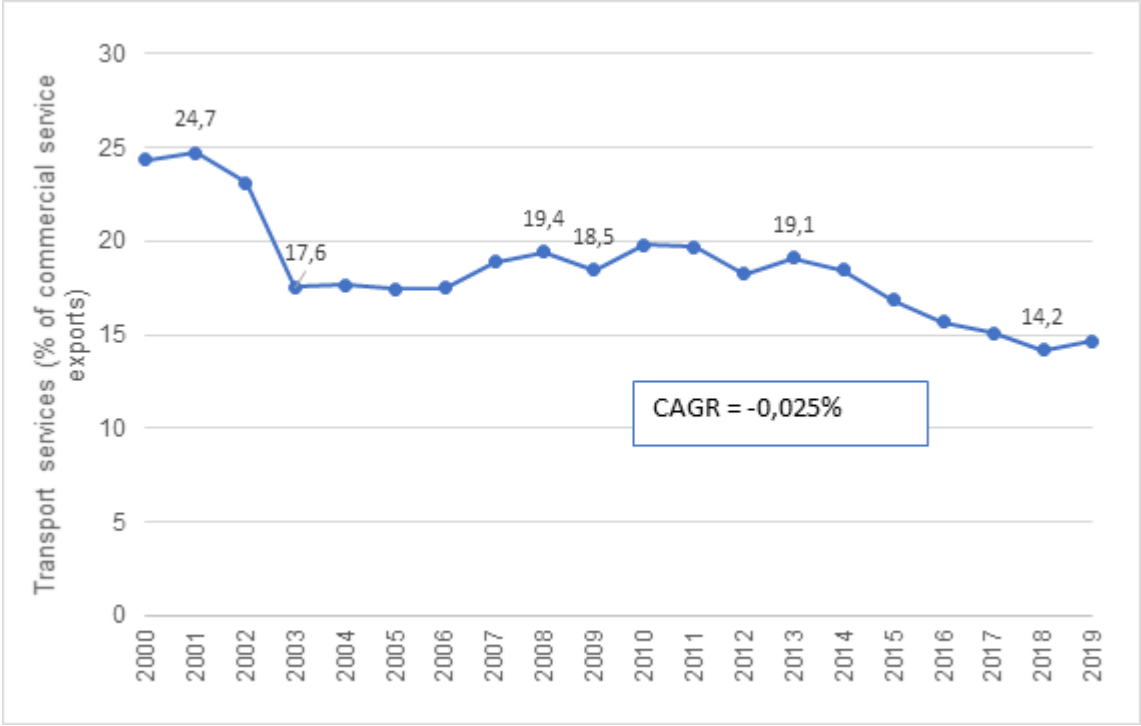

Figure 1.85. Transport services of South Africa

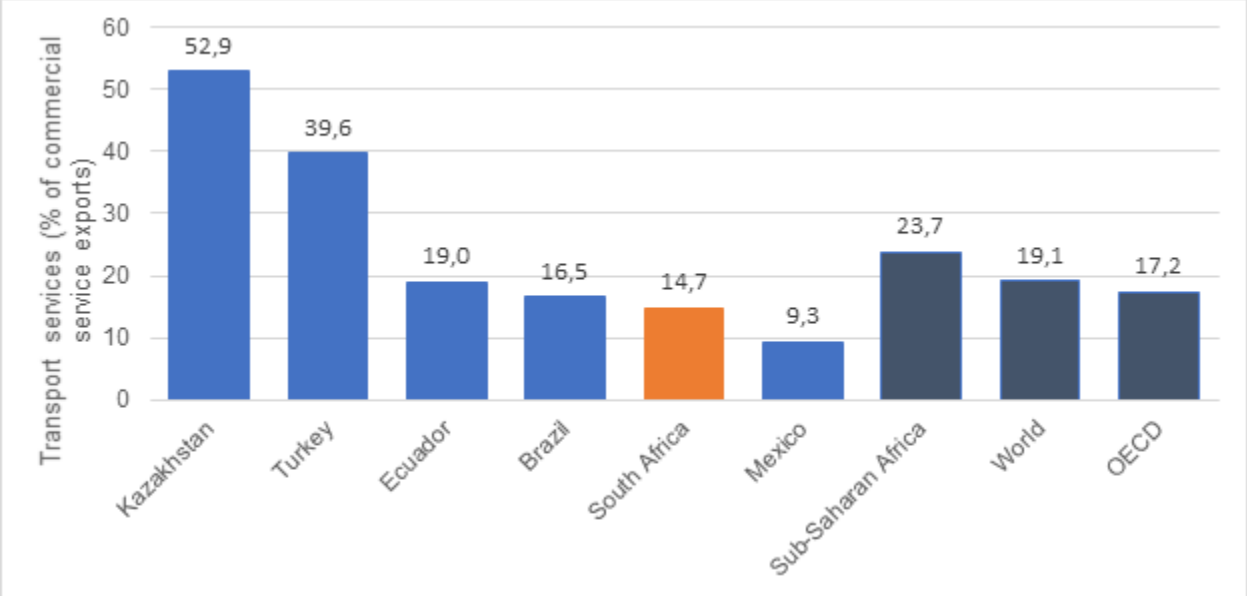

Figure 1.86. Transport services, 2019

1.7.7 Normalized indicators values and composite index for the «Export growth and competitiveness» factor

The analysis of normalized indicators and composite index shows that in terms of export growth and competitiveness index, South Africa is below average and more progress needs to be made in order to make use of the country's real potentials (Figure 1.87).

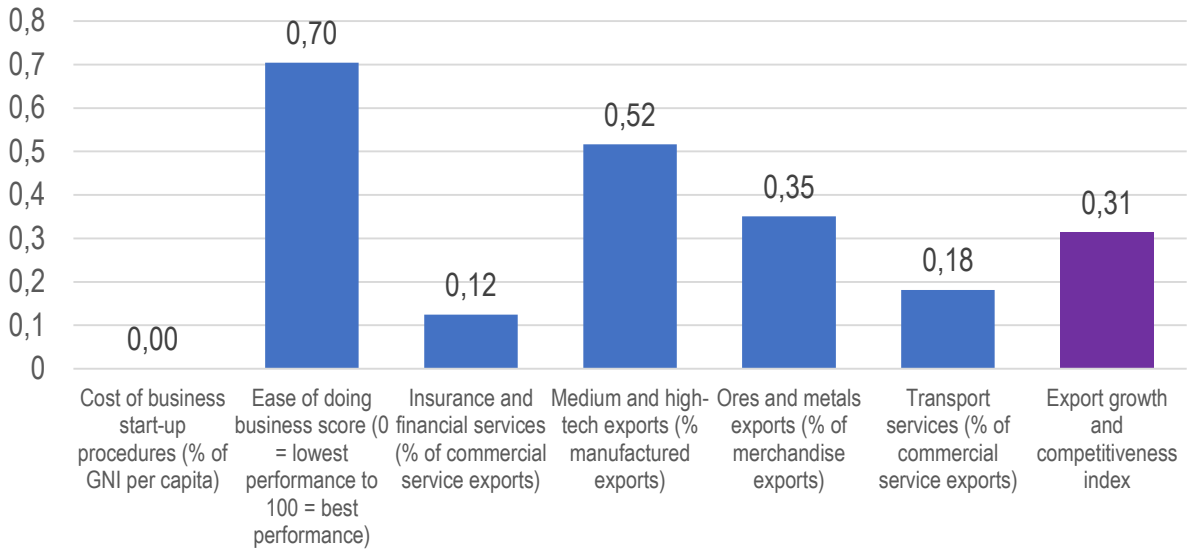

Figure 1.87. Normalized indicators values and a composite index for the «Export growth and competitiveness» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.8 Renewable energy growth

1.8.1 Access to electricity (% of population)

Access to electricity is the percentage of population with access to electricity. Electrification data are collected from industry, national surveys, and international sources.

Data for access to electricity are collected among different sources: mostly data from nationally representative household surveys (including national censuses) were used. Survey sources include Demographic and Health Surveys (DHS) and Living Standards Measurement Surveys (LSMS), Multi-Indicator Cluster Surveys (MICS), the World Health Survey (WHS), other nationally developed and implemented surveys, and various government agencies (for example, ministries of energy and utilities). Given the low frequency and the regional distribution of some surveys, several countries have gaps in available data. To develop the historical evolution and starting point of electrification rates, a simple modeling approach was adopted to fill in the missing data points - around 1990, around 2000, and around 2010. Therefore, a country can have a continuum of zero to three data points. There are 42 countries with zero data point and the weighted regional average was used as an estimate for electrification in each of the data periods. 170 countries have between one and three data points and missing data are estimated by using a model with region, country, and time variables. The model keeps the original observation if data is available for any of the time periods. This modeling approach allowed the estimation of

electrification rates for 212 countries over these three time periods (Indicated as "Estimate"). Notation "Assumption" refers to the assumption of universal access in countries classified as developed by the United Nations. Data begins from the year in which the first survey data is available for each country.

In South Africa, population's access to electricity has increased substantially from 71.8 per cent in the year 2000 to 91.2 per cent in 2018 (Figure 1.88). Considering that the benchmark countries provided electricity 100 per cent of their population, there is still some progress need to be made (Figure 1.89).

Source: World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.

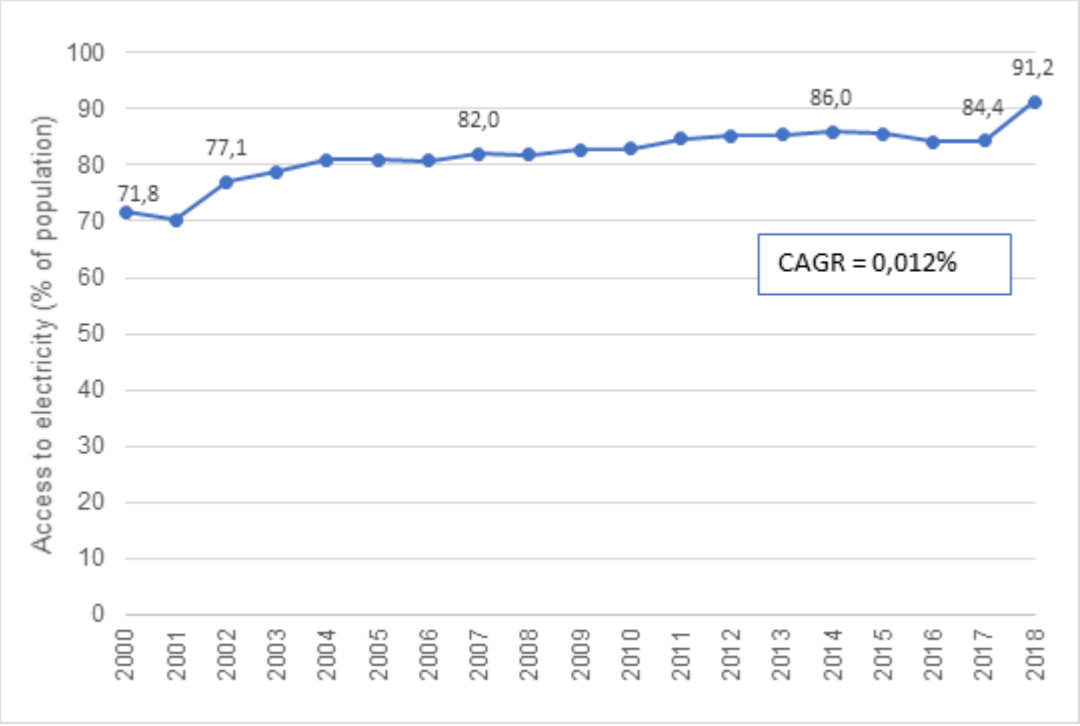

Figure 1.88. Access to electricity in South Africa

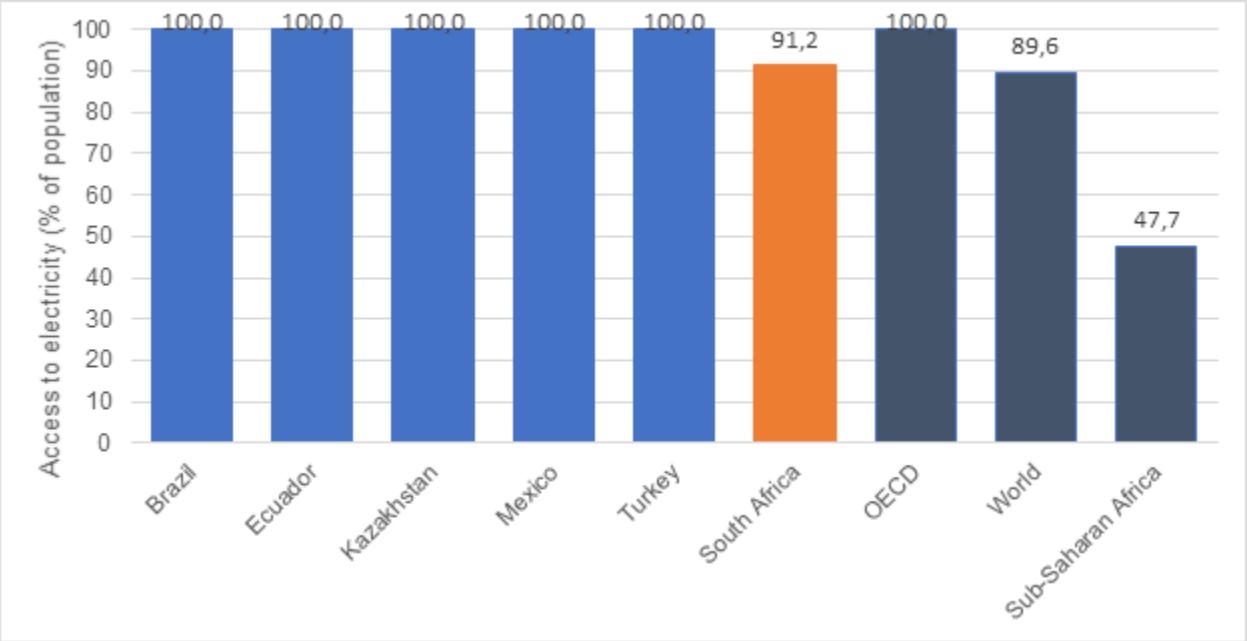

Figure 1.89. Access to electricity, 2018

1.8.2 Combustible renewables and waste (% of total energy)

Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use.

Energy data are compiled by the International Energy Agency (IEA). IEA data for economies that are not members of the organization for Economic Co-operation and Development (OECD) are based on national energy data adjusted to conform to annual questionnaires completed by OECD member governments.

In South Africa, 8.02 per cent of total energy is produced by combustible renewables and waste. In Sub-Saharan Africa the use of combustible renewables and waste are extremely high compared to South Africa (Figure 1.90 & 1.91).

Source: IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

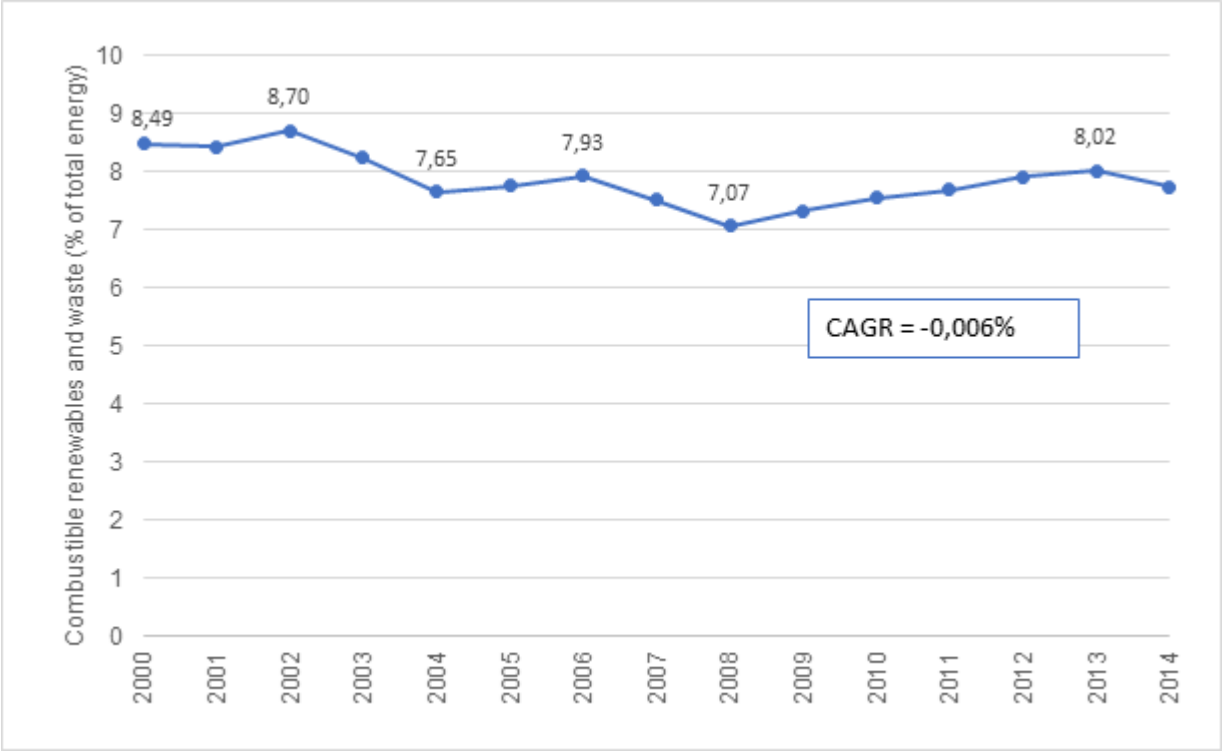

Figure 1.90. Combustible renewables and waste of South Africa

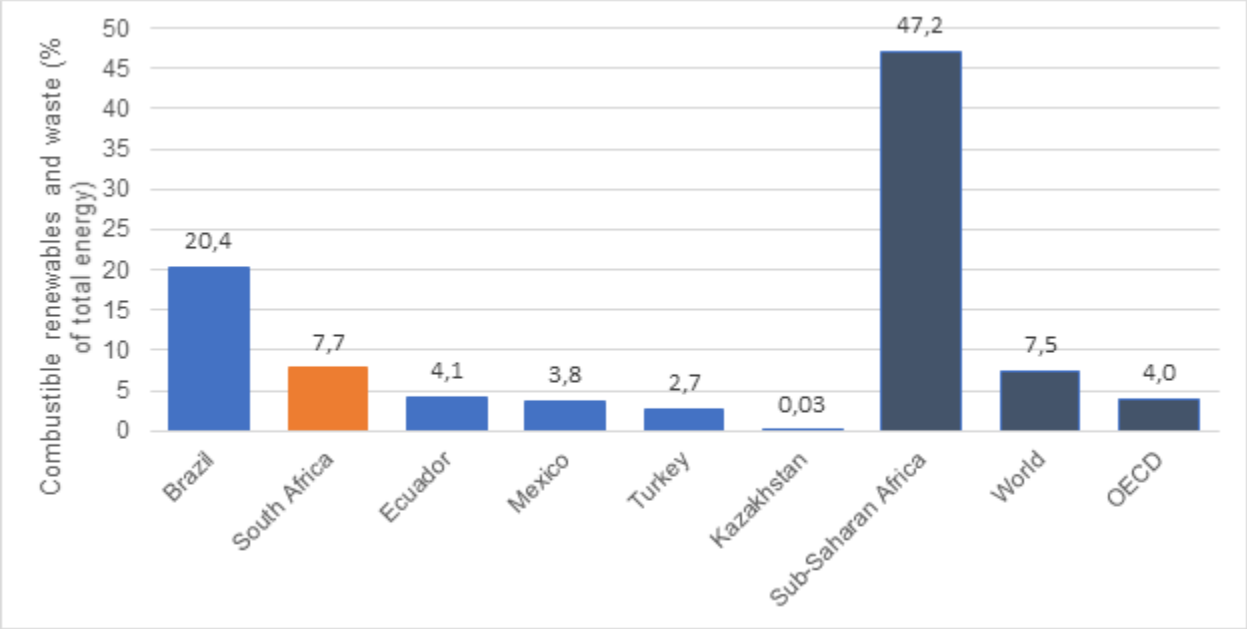

Figure 1.91. Combustible renewables and waste, 2014

1.8.3 Electricity production from renewable sources, excluding hydroelectric (% of total)

Electricity production from renewable sources, excluding hydroelectric, includes geothermal, solar, tides, wind, biomass, and biofuels.

Electricity production from renewable sources (% of total) is the share of electricity produced by geothermal, solar photovoltaic, solar thermal, tide, wind, industrial waste, municipal waste, primary solid biofuels, biogases, biogasoline, biodiesels, other liquid biofuels, no specified primary biofuels and waste, and charcoal in total electricity production which is the total number of GWh generated by power plants separated into electricity plants and CHP plants. Hydropower is excluded. The International Energy Agency (IEA) compiles data on energy inputs used to generate electricity. IEA data for countries that are not members of the organization for Economic Co-operation and Development (OECD) are based on national energy data adjusted to conform to annual questionnaires completed by OECD member governments. In addition, estimates are sometimes made to complete major aggregates from which key data are missing, and adjustments are made to compensate for differences in definitions. The IEA makes these estimates in consultation with national statistical offices, oil companies, electric utilities, and national energy experts.

Electricity production from renewables in South Africa has been traditionally low – up until 2013, it was only 0.15 per cent. However, more recently a serious jump has been observed with an increasing share of renewables in electricity reaching to 1.93 per cent (Figure 1.92). The share of renewables in electricity generation in South Africa is still low compared to the other countries, but this figure can be expeted to rise considering more recent figures (Figure 1.93).

Source: IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

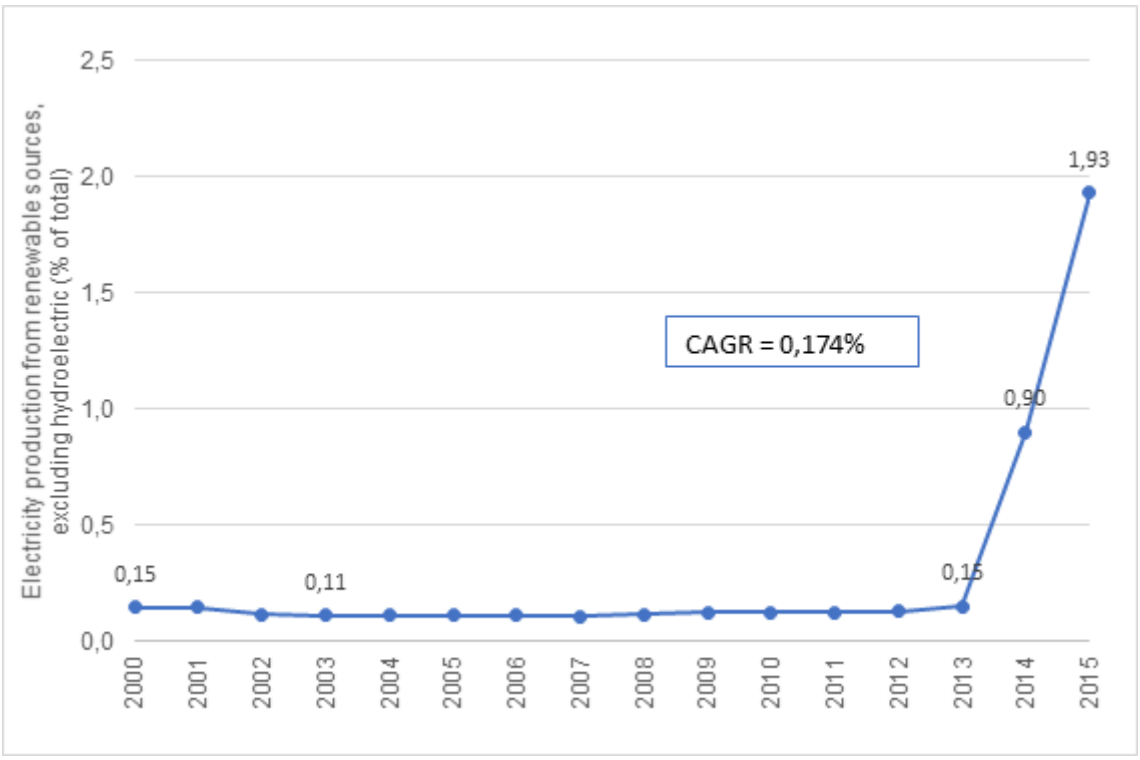

Figure 1.92. Electricity production from renewable sources (excluding hydroelectric), South Africa

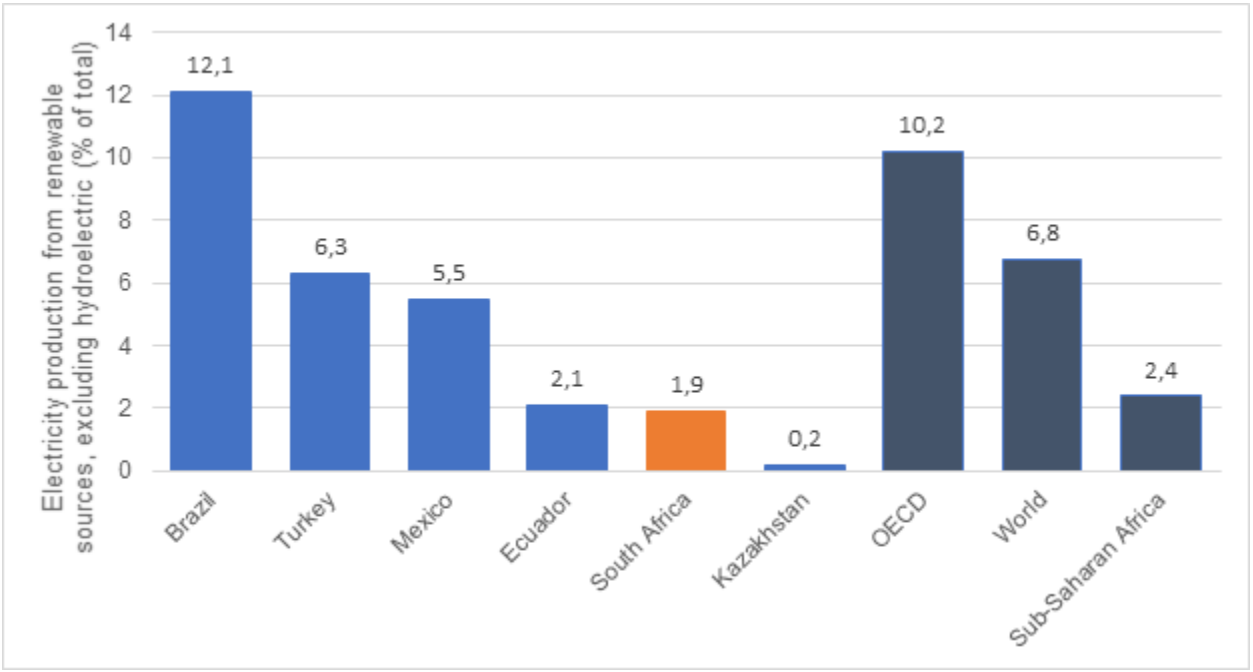

Figure 1.93. Electricity production from renewable sources (excluding hydroelectric), 2015

1.8.4 GDP per unit of energy use (PPP $ per kg of oil equivalent)

GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to current international dollars using purchasing power parity rates based on the 2017 ICP round. An international dollar has the same purchasing power over GDP as a U.S. dollar has in the United States.

GDP per unit of energy use in South Africa has been on a constant increase in the past couple of decades. However, the comparison with other benchmark countries indicate that South Africa needs to make more progress to increase the added value of the use of energy (Figure 1.94 & 1.95).

Source: IEA Statistics © OECD/IEA 2014 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

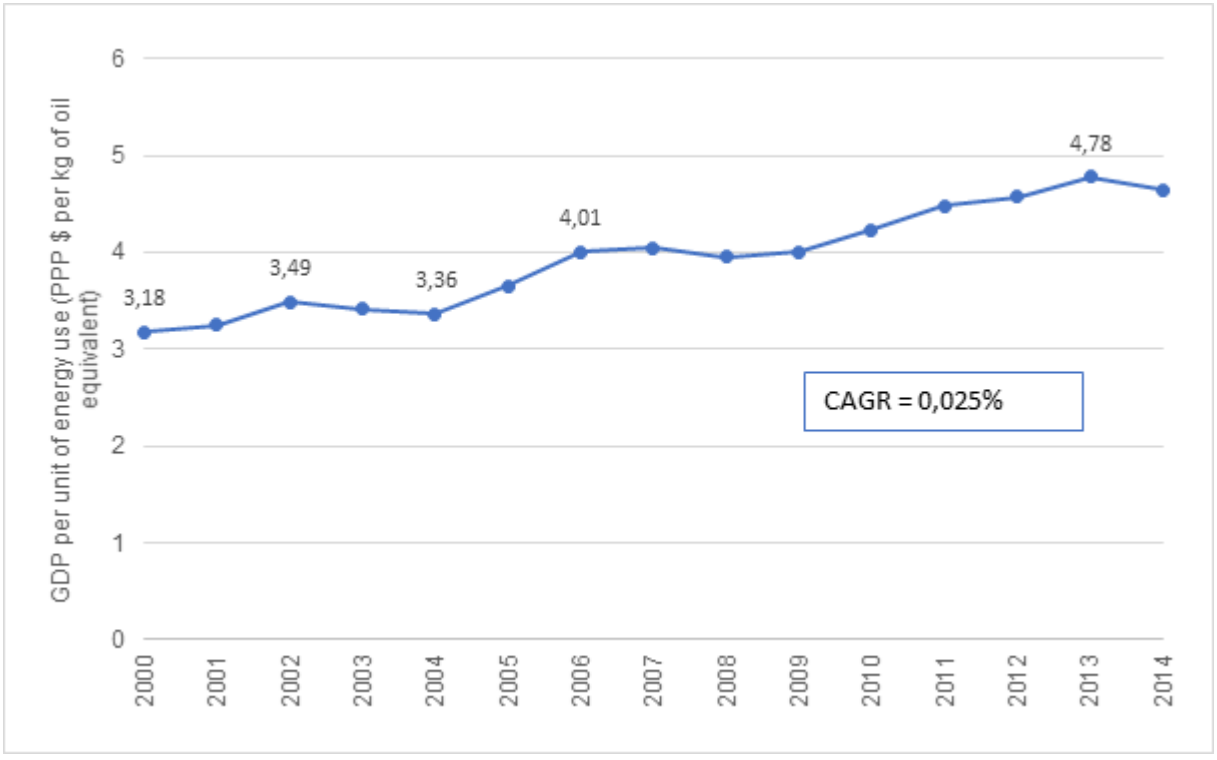

Figure 1.94. GDP per unit of energy use (PPP) in South Africa

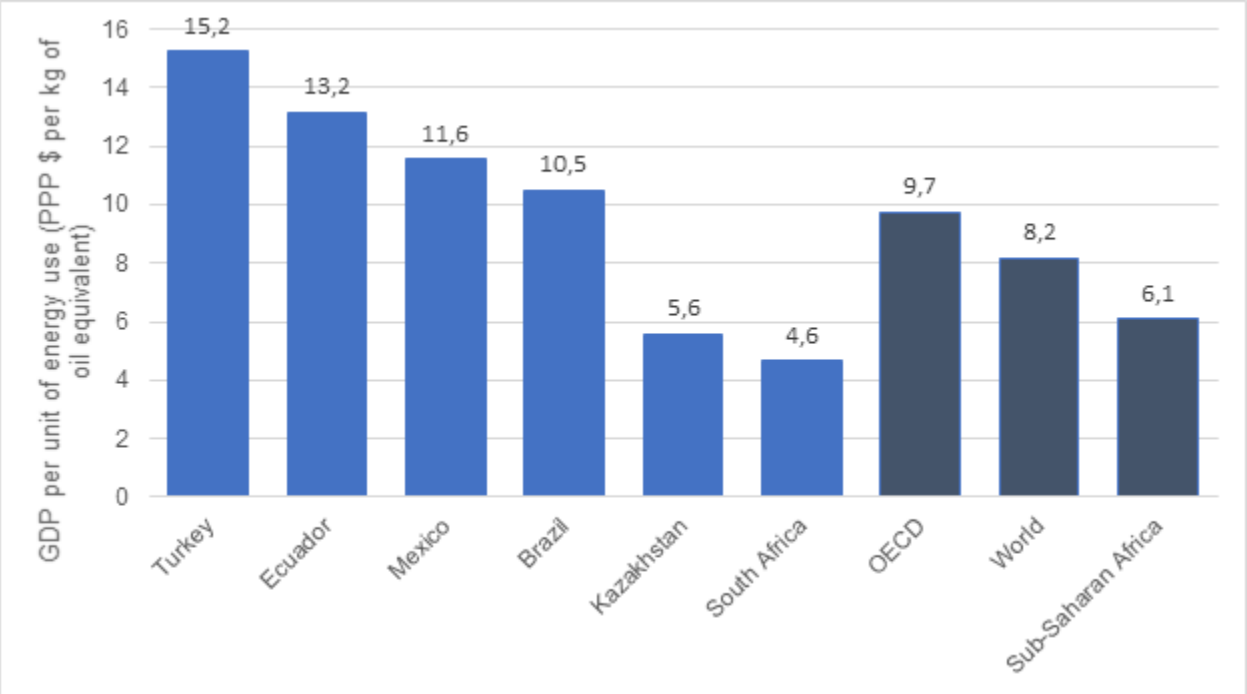

Figure 1.95. GDP per unit of energy use (PPP), 2014

1.8.5 Renewable electricity output (% of total electricity output)

Renewable electricity is the share of electricity generated by renewable power plants in total electricity generated by all types of plants.

Following the increasing share of renewables use in energy generation, the electricity output generated from renewables is also in increase in South Africa. Since 2013, the share of renewable electricity output has reached to 2.26 per cent and is expected to rise in the years to come. However, this figure is still the lowest among the benchmark countries (Figure 1.96 & 1.97).

Source: IEA Statistics © OECD/IEA 2018 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/

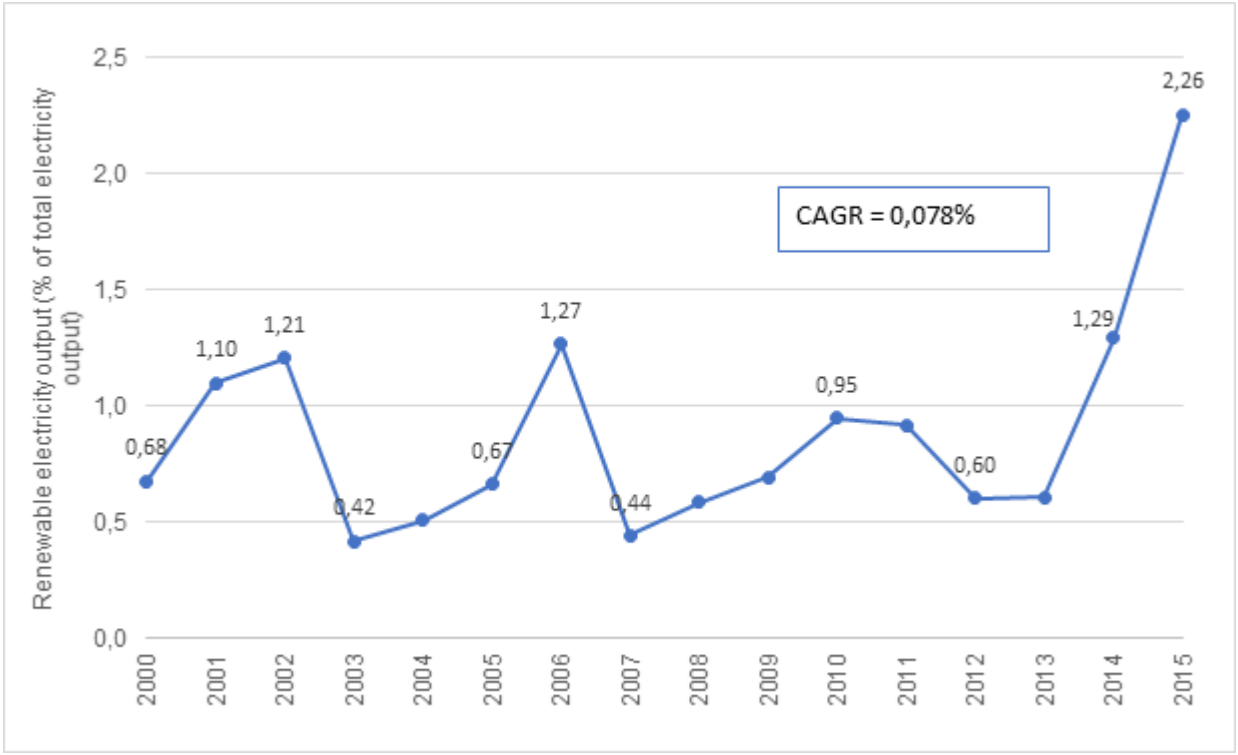

Figure 1.96. Renewable electricity output of South Africa

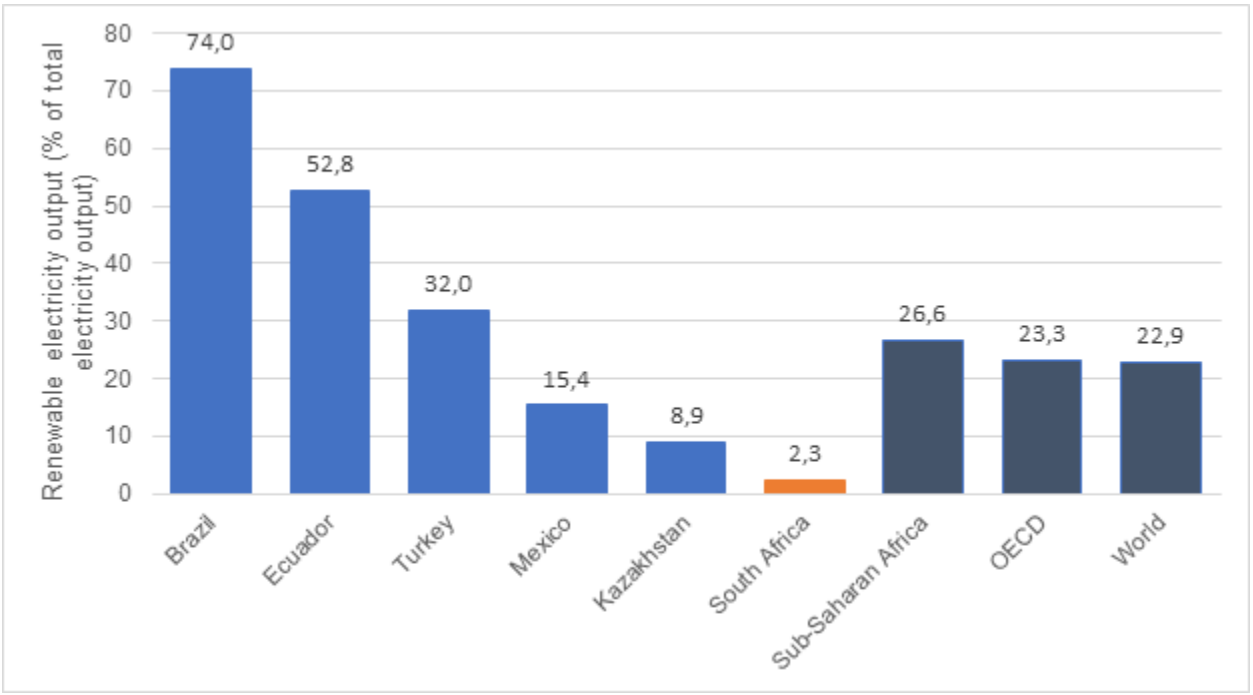

Figure 1.97. Renewable electricity output, 2015

1.8.6 Renewable energy consumption (% of total final energy consumption)

Renewable energy consumption is the share of renewable energy in total final energy consumption.

Despite of the increasing use of renewables for energy generation, renewable energy consumption figures remained steady around 17 per cent as percentage of total final energy consumption (Figure 1.98). With these figures South Africa ranks second after Brazil, but is well behind the average of the Sub-Saharan African countries (Figure 1.99).

Source: World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.

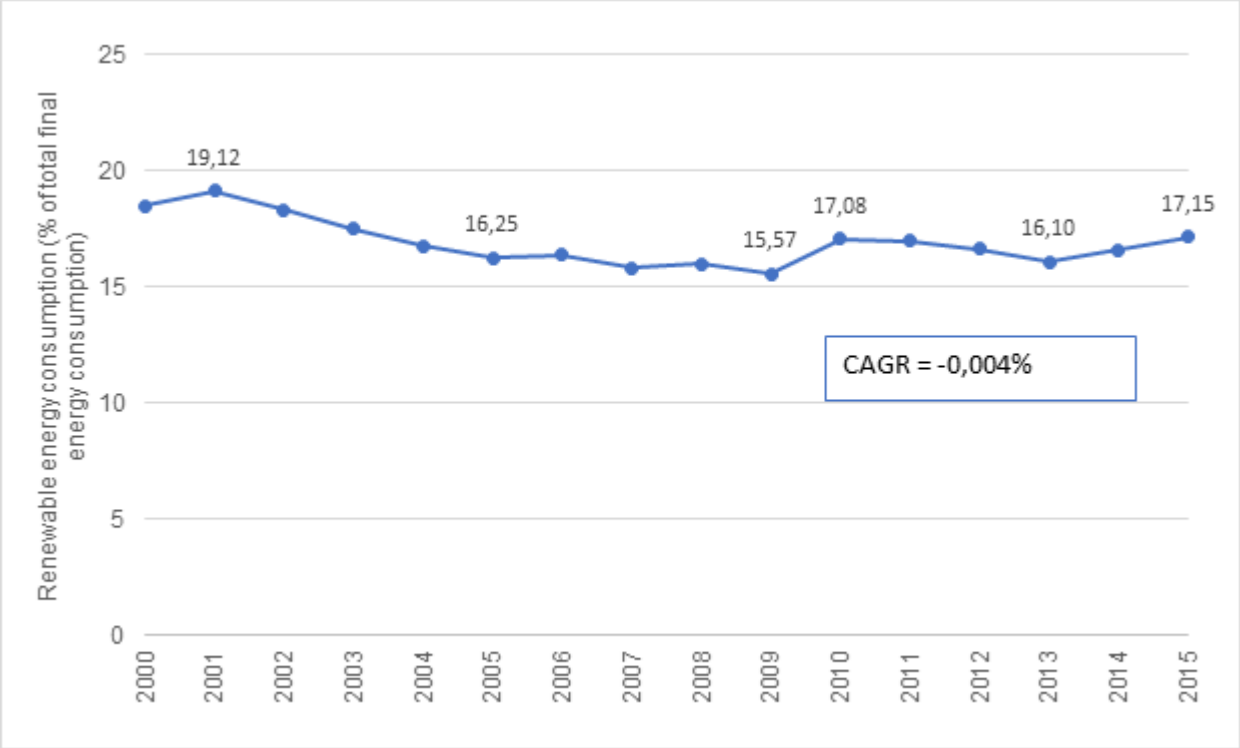

Figure 1.98. Renewable energy consumption of South Africa

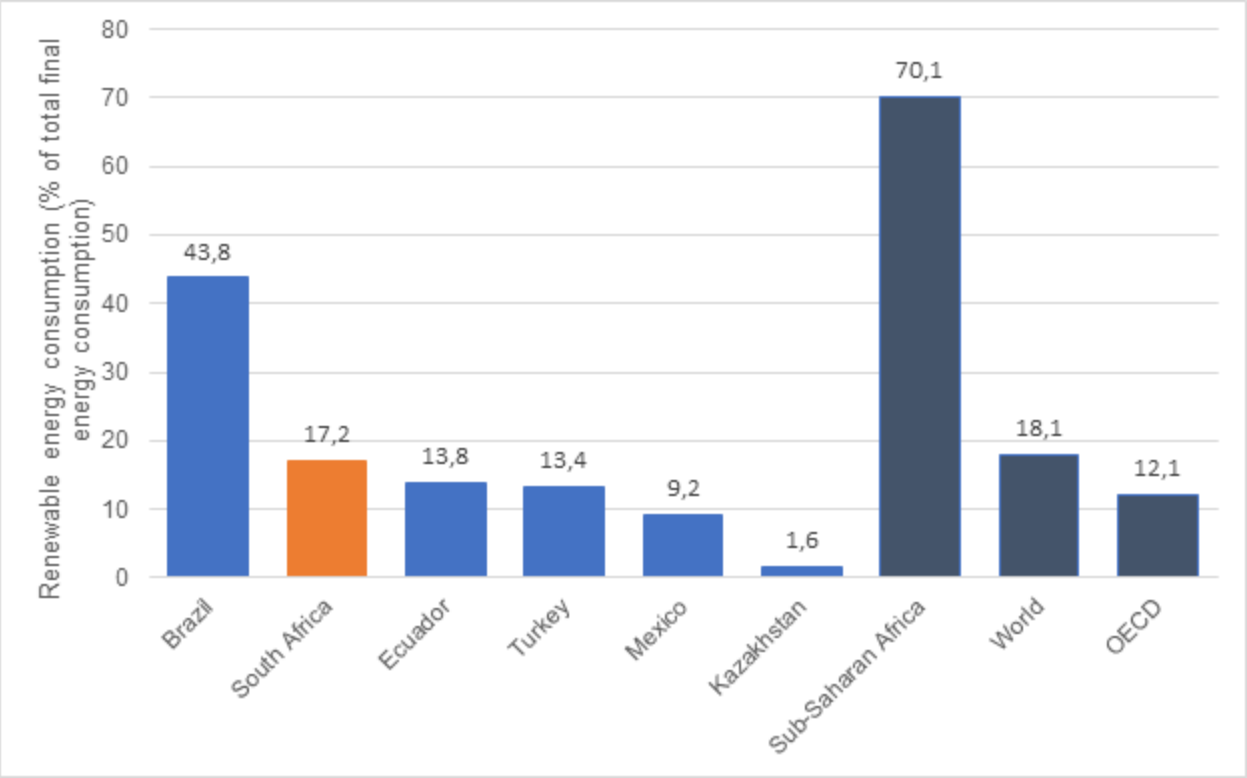

Figure 1.99. Renewable energy consumption, 2015

1.8.7 Normalized indicators values and composite index for the «Renewable energy growth» factor

Although South Africa is relatively better positioned considering access to electricity and GDP per unit of energy use, total renewable energy growth index of the country is still low. However, looking at the recent trends, the country's renewable energy performance is expected to grow (Figure 1.100).

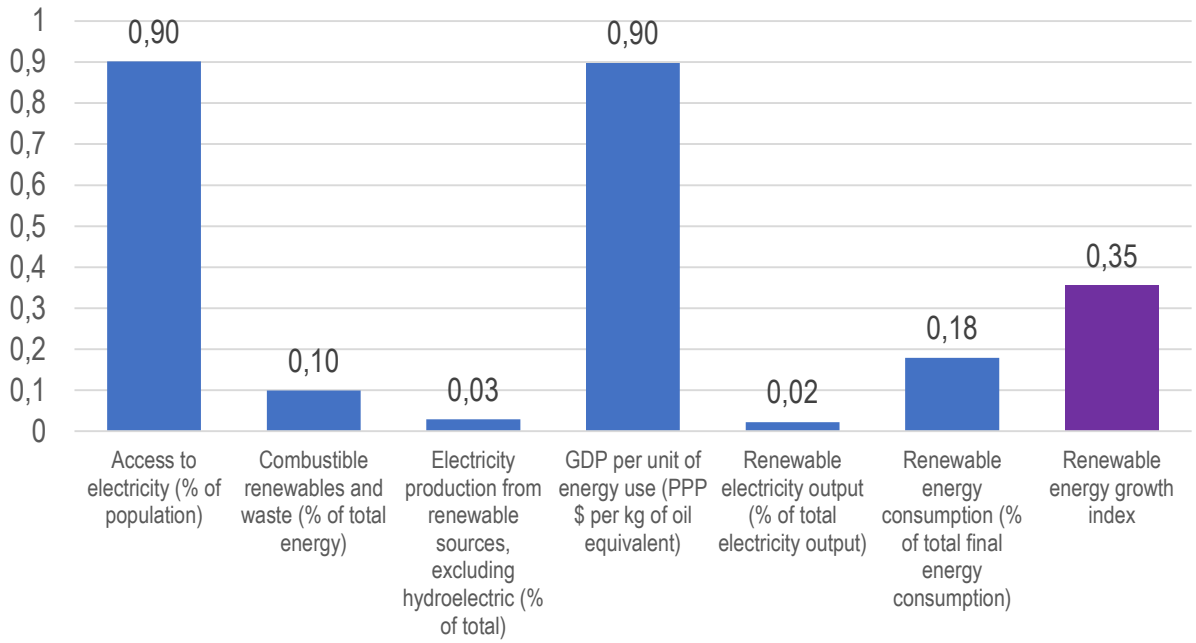

Figure 1.100. Normalized indicators values and a composite index for the «Renewable energy growth» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.9 Skills development

1.9.1 Literacy rate, adult total (% of people age 15 and above)

Literacy statistics for most countries cover the population ages 15 and older, but some include younger ages or are confined to age ranges that tend to inflate literacy rates. The youth literacy rate for ages 15-24 reflects recent progress in education. It measures the accumulated outcomes of primary education over the previous 10 years or so by indicating the proportion of the population who have passed through the primary education system and acquired basic literacy and numeracy skills. Generally, literacy also encompasses numeracy, the ability to make simple arithmetic calculations.

Data on literacy are compiled by the UNESCO Institute for Statistics based on national censuses and household surveys and, for countries without recent literacy data, using the Global Age-Specific Literacy Projection Model (GALP). For detailed information, see www.uis.unesco.org.

In South Africa, adult literacy rate has been over 90 per cent in average. However, a decline was observed in 2017, which needs an investigation to understand the underlying reasons (Figure

1.101). With these figures, adult litercy in South Africa is just behind the other benchmark countries, and above the World average (Figure 1.102).

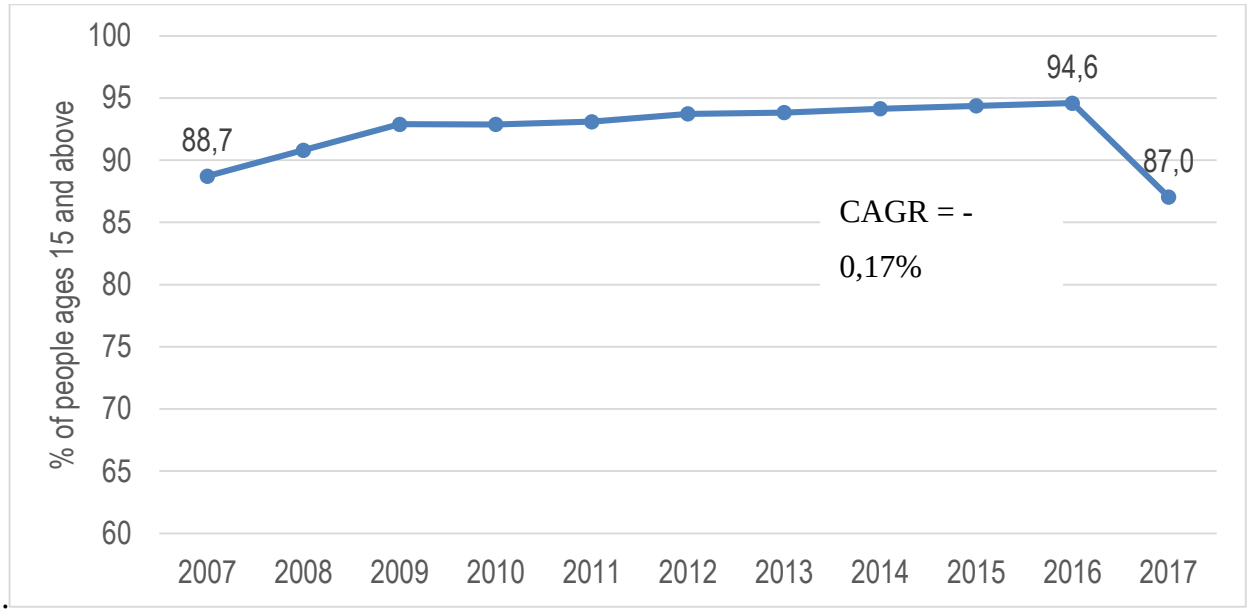

Figure 1.101. Literacy rate in South Africa

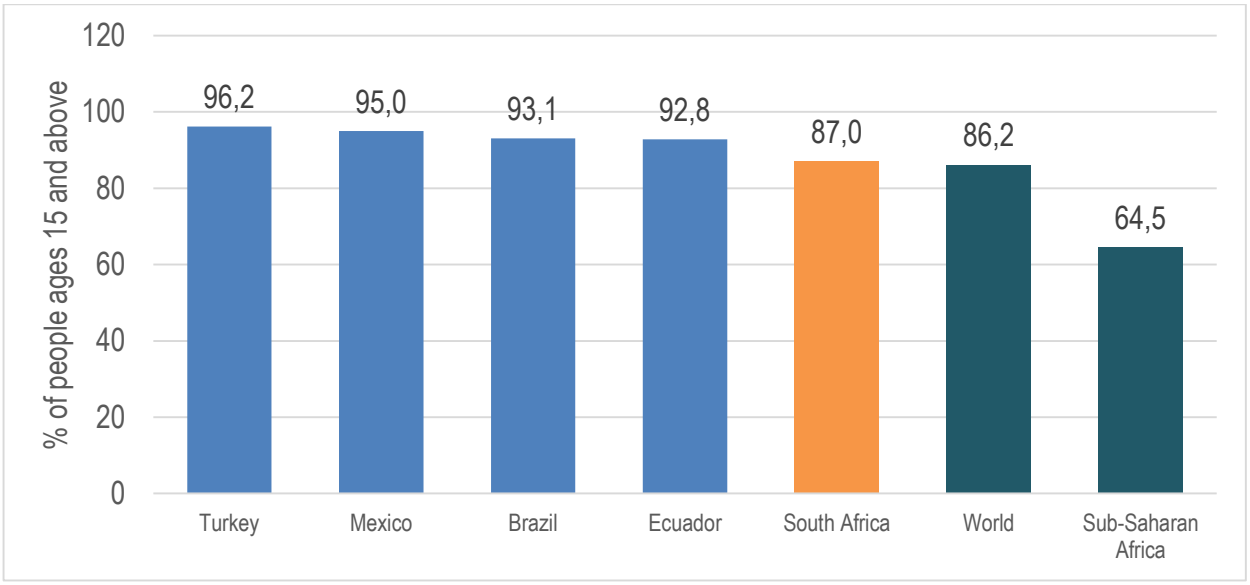

Figure 1.102. Literacy rate, adult total, 2018

1.9.2 Educational attainment, at least Bachelor's or equivalent, population 25+, total (%) (cumulative)

It is calculated by dividing the number of population ages 25 and older who attained or completed bachelor's or equivalent by the total population of the same age group and multiplying by 100. The number 0 means zero or small enough that the number would round to zero.

Data are collected by the UNESCO Institute for Statistics mainly from national population census, household survey, and labour force survey. All the data are mapped to the International Standard Classification of Education (ISCED) to ensure the comparability of education programs at the international level. The current version was formally adopted by UNESCO Member States in 2011.

Eucational attainment in South Africa has been increasing, however it is still well behind the other benchmark countries and the World average (Figure 1.103 & 1.104).

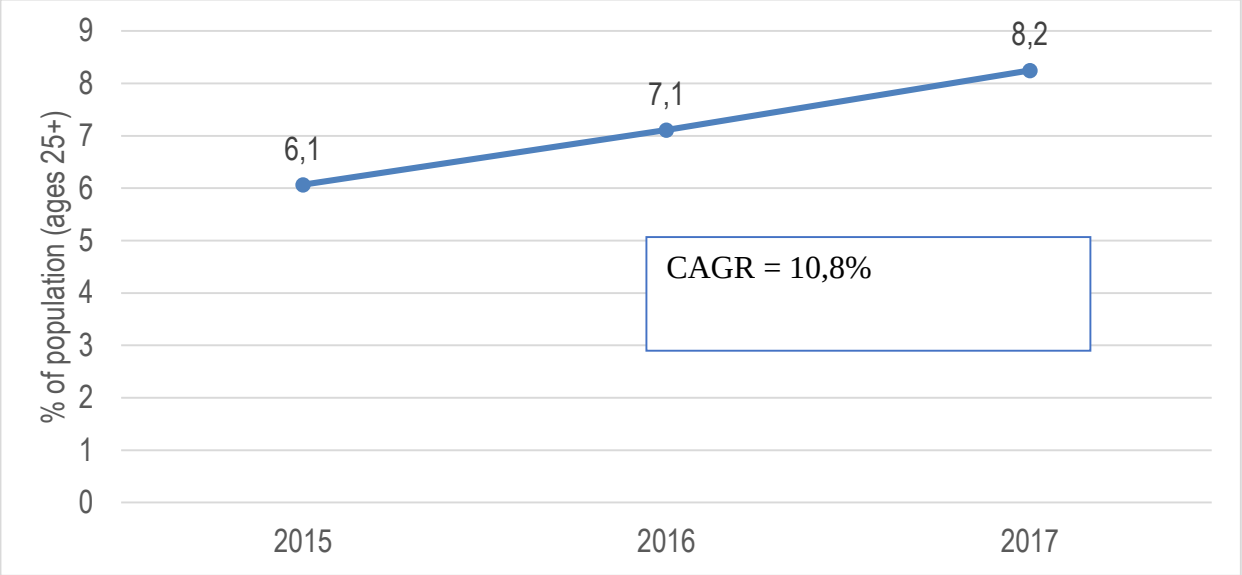

Figure 1.103. Educational attainment, at least Bachelor's or equivalent in South Africa

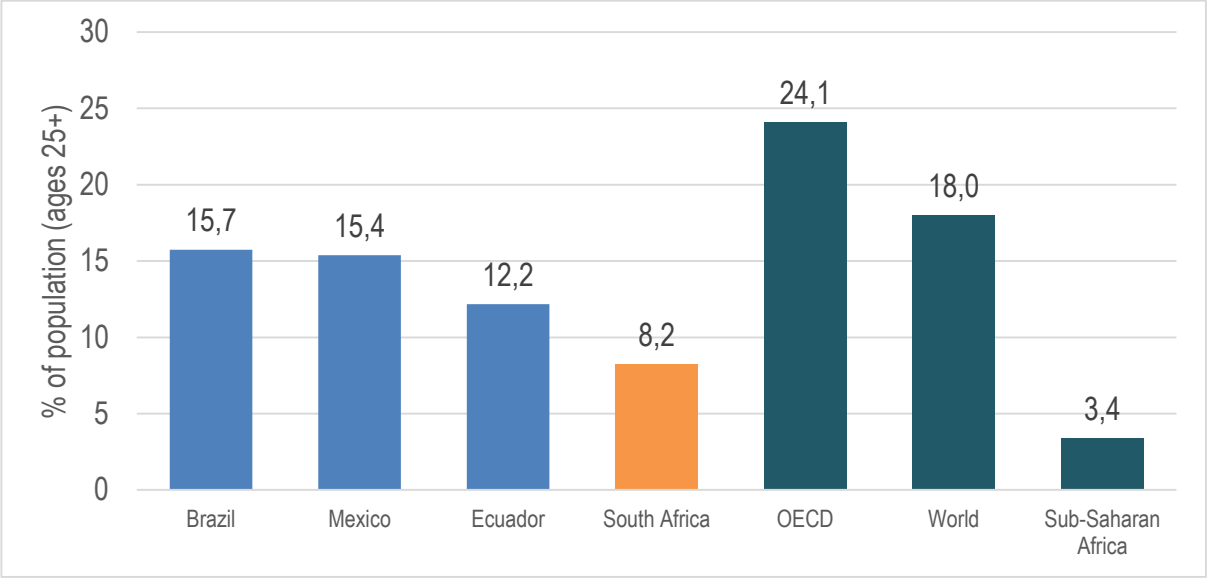

Figure 1.104. Educational attainment, at least Bachelor's or equivalent, 2017

1.9.3 Educational attainment, at least completed post-secondary, population 25+, total (%) (cumulative)

It is calculated by dividing the number of population ages 25 and older who attained or completed post-secondary non-tertiary education by the total population of the same age group and multiplying by 100. The number 0 means zero or small enough that the number would round to zero.

Data are collected by the UNESCO Institute for Statistics mainly from national population census, household survey, and labour force survey. All the data are mapped to the International Standard Classification of Education (ISCED) to ensure the comparability of education programs at the international level. The current version was formally adopted by UNESCO Member States in 2011.

Regarding post-secondary educational attainment, an increase was observed from 2001 to 2015 in South Africa. However, starting from 2016 a sharp decrease was observed to 2011 levels with 13.7 percent (Figure 1.105). With this figures, South Africa is behind all the benchmark countries and the World (Figure 1.106).

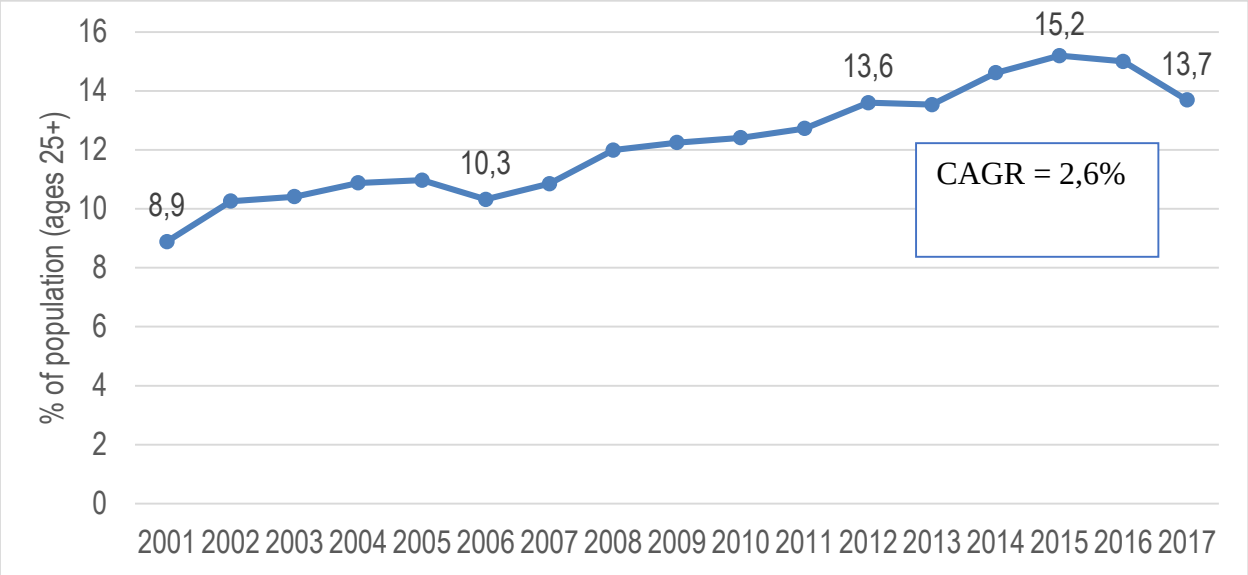

Figure 1.105. Educational attainment, at least completed post-secondary, in South Africa

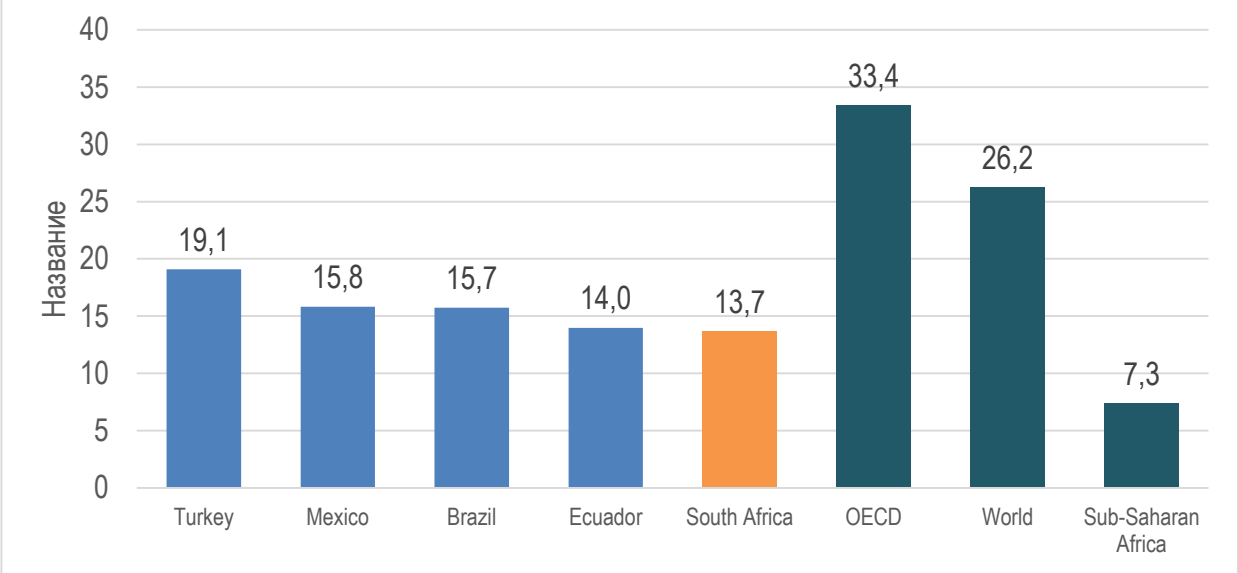

Figure 1.106. Educational attainment, at least completed post-secondary, 2017

1.9.4 Mean years of schooling (years)

Definition: Average number of years of education received by people ages 25 and older, converted from education attainment levels using official durations of each level.

Mean schooling years in South Africa has slightly increased since the year 2000. However, there is almost no progress since 2010 (Figure 1.107). The country has a comparable position with the other countries benchmarked (Figure 1.108).

Source: UNESCO Institute for Statistics (2020), Barro and Lee (2018), ICF Macro Demographic and Health Surveys, UNICEF Multiple Indicator Cluster Surveys and OECD (2019b).

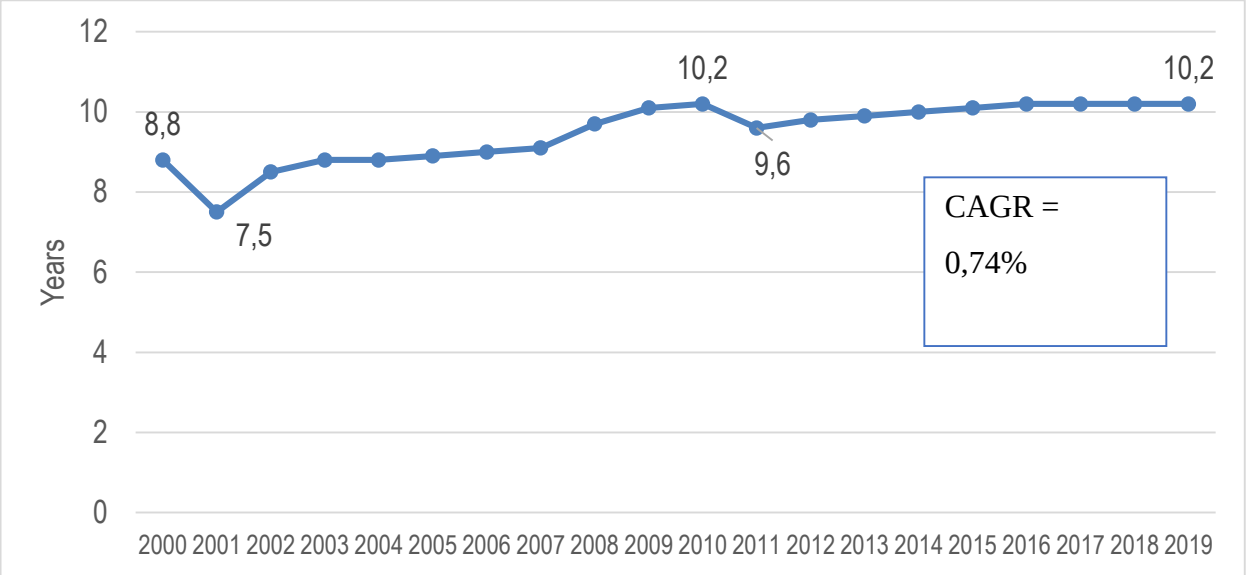

Figure 1.107. Mean years of schooling in South Africa

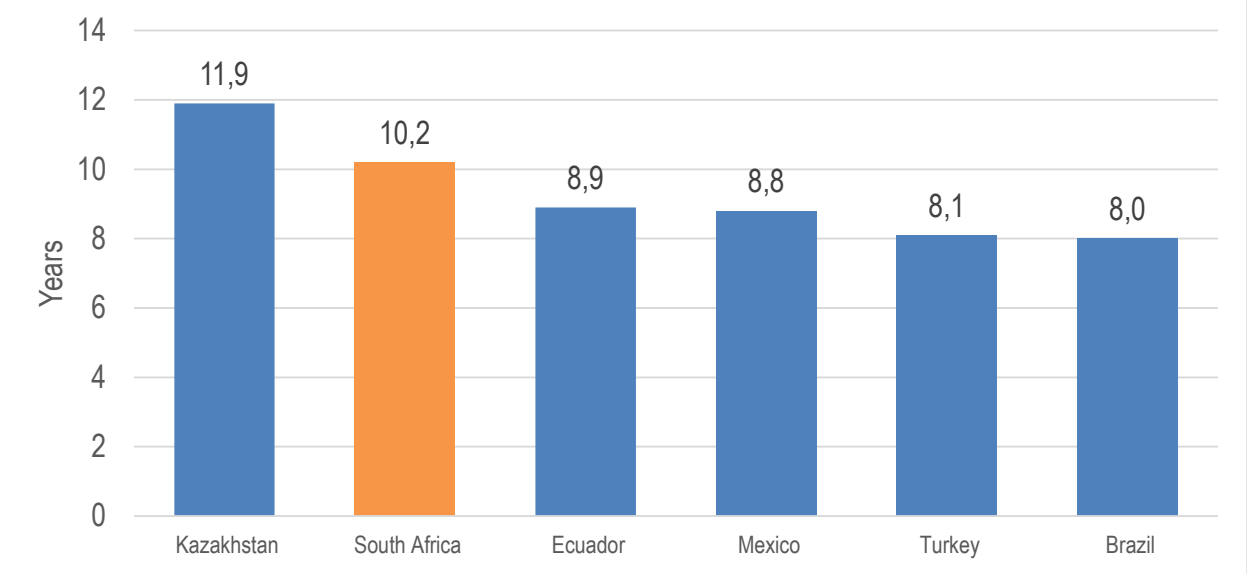

Figure 1.108. Mean years of schooling, 2019

1.9.5 Expenditure on tertiary education (% of government expenditure on education)

The share of expenditure on tertiary education to total government expenditure on education is calculated by dividing government expenditure on tertiary education by total government expenditure on education (all levels combined) and multiplying by 100. Aggregate data are based on World Bank estimates.

Data on education are collected by the UNESCO Institute for Statistics from official responses to its annual education survey. All the data are mapped to the International Standard Classification of Education (ISCED) to ensure the comparability of education programs at the international level. The current version was formally adopted by UNESCO Member States in 2011.

The share of tertiary education as percentage of the government's total education expenditure represents 15.3 per cent in South Africa. This represents only a slight increase compared to previous years (Figure 1.108). Considering the other benchmark countries, and the World and Sub-Saharan African countries, South Africa has the lowest expenditure on tertiary education (Figure 1.109)

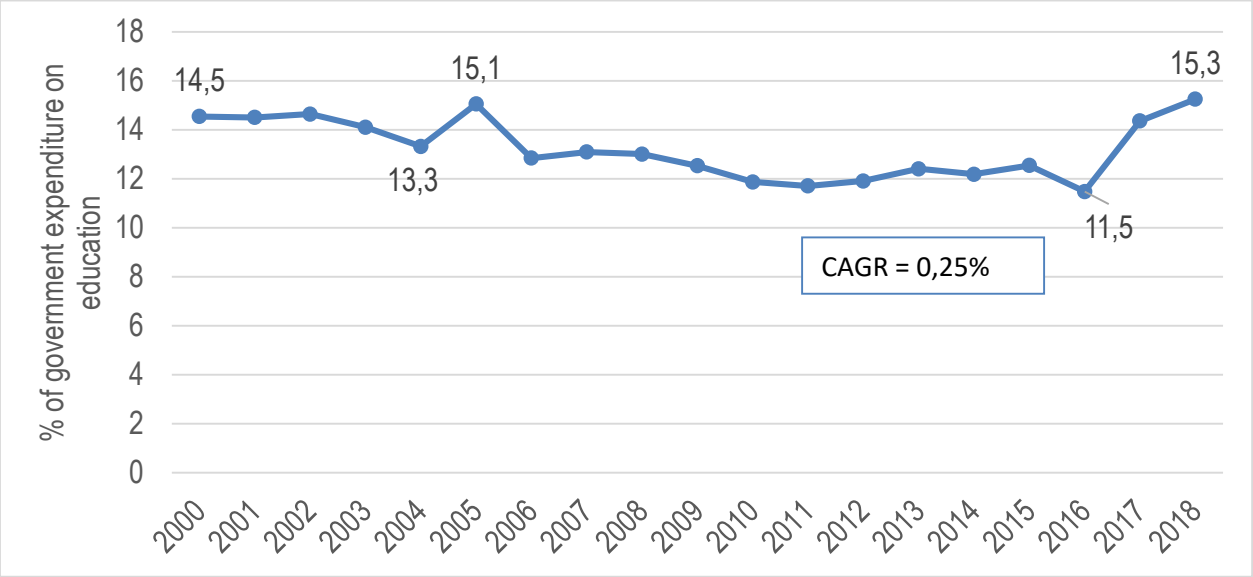

Figure 1.109. Expenditure on tertiary education in South Africa

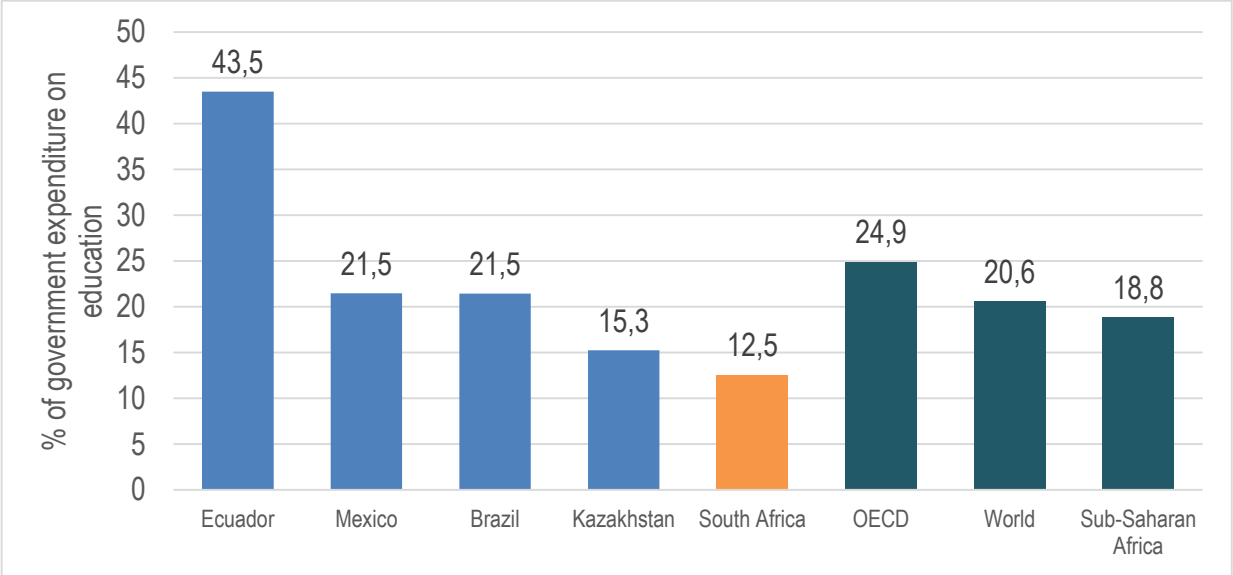

Figure 1.110. Expenditure on tertiary education (% of government expenditure on education), 2015

1.9.6 School enrollment, tertiary (% gross)

Gross enrollment ratio for tertiary school is calculated by dividing the number of students enrolled in tertiary education regardless of age by the population of the age group which officially corresponds to tertiary education and multiplying by 100.

Data on education are collected by the UNESCO Institute for Statistics from official responses to its annual education survey. All the data are mapped to the International Standard Classification of Education (ISCED) to ensure the comparability of education programs at the international level. The current version was formally adopted by UNESCO Member States in 2011. Population data are drawn from the United Nations Population Division. Using a single source for population data standardizes definitions, estimations, and interpolation methods, ensuring a consistent methodology across countries and minimizing potential enumeration problems in national censuses.

The reference years reflect the school year for which the data are presented. In some countries the school year spans two calendar years (for example, from September 2010 to June 2011); in these cases, the reference year refers to the year in which the school year ended (2011 in the example).

Although tertiary school enrollment is increasing in South Africa, the figures are still far from the global levels (Figure 1.111 & 1.112).

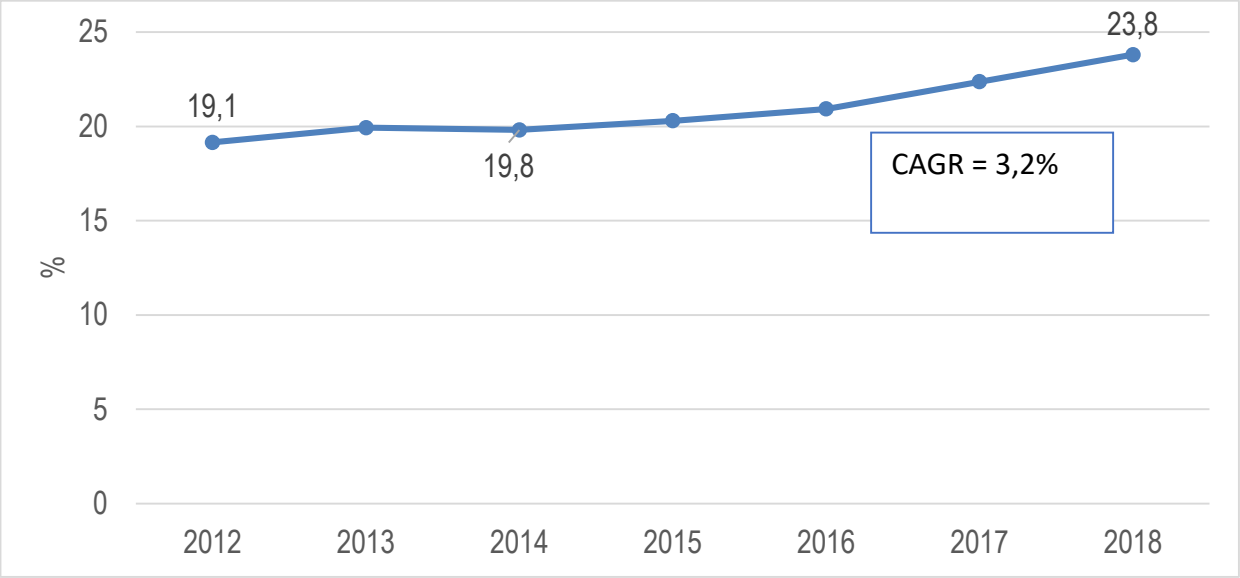

Figure 1.111. School enrollment (tertiary) in South Africa

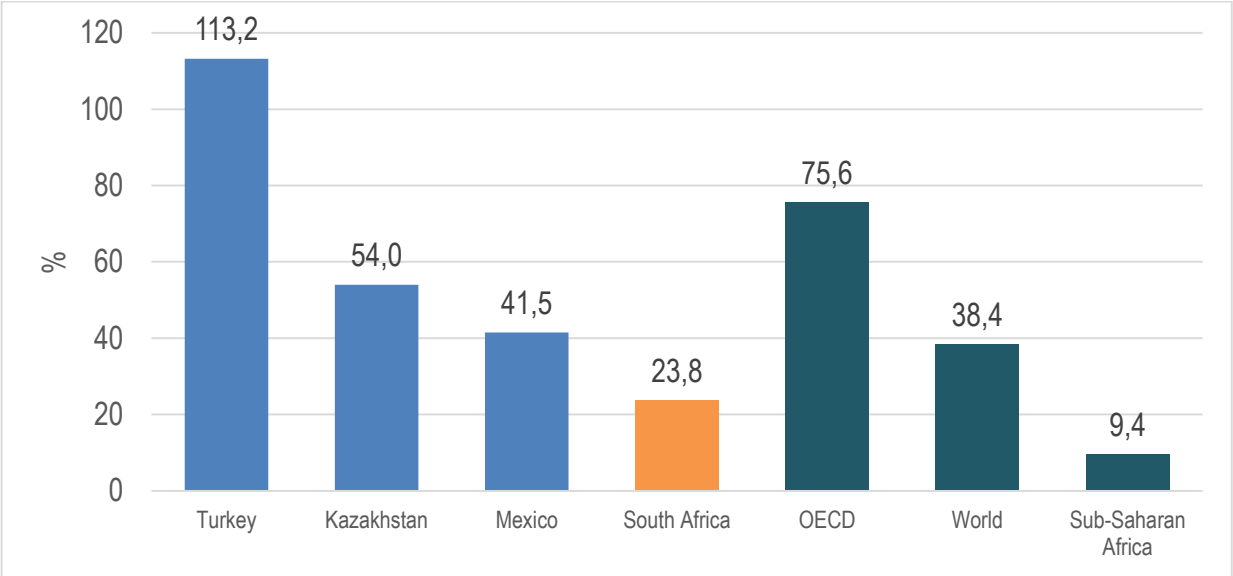

Figure 1.112. School enrollment (tertiary), 2018

1.9.7 Normalized indicators values and composite index for the «Skills development» factor

South Africa's position in literacy rate and mean years of schooling are relatively better, but there is still a lot to be done to improve tertiary school enrollment and educational attainment in bachelor or post-secondary education. In total, the skills development index of South Africa is well below the average (Figure 1.113).

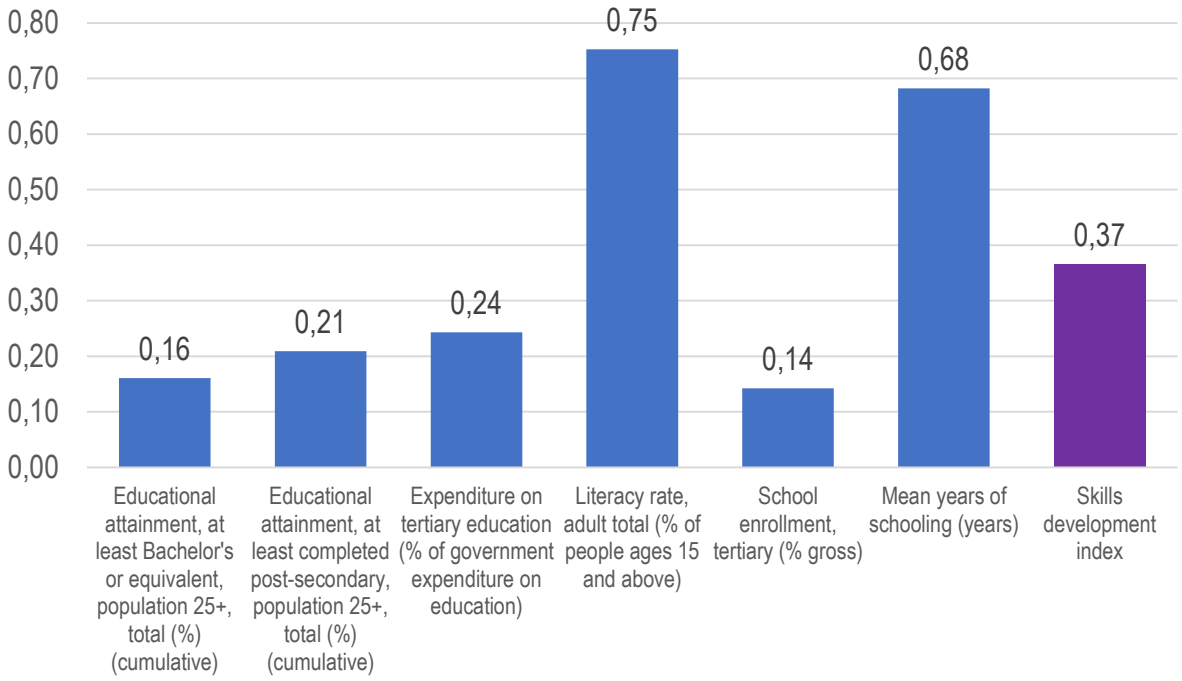

Figure 1.113. Normalized indicators values and a composite index for the «Skills development» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.10 Affordable food

1.10.1 Food production index (2004-2006 = 100%)

The agricultural production index is prepared by the Food and Agriculture Organization of the United Nations (FAO). The FAO indices of agricultural production show the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 2004-2006. They are based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. The resulting aggregate represents, therefore, disposable production for any use except as seed and feed. All the indices at the country, regional and world levels are calculated by the Laspeyres formula*. Production quantities of each commodity are weighted by 2004-2006 average international commodity prices and summed for each year. To obtain the index, the aggregate for a given year is divided by the average aggregate for the base period 2004-2006. Since the FAO indices are based on the concept of agriculture as a single enterprise, amounts of seed and feed are subtracted from the production data to avoid double counting, once in the production data and once with the crops or livestock produced from them. Deductions for seed (in the case of eggs, for hatching) and for livestock and poultry feed apply to both domestically produced and imported commodities. They cover only primary agricultural products destined to animal feed (e.g., maize, potatoes, milk, etc.). Processed and semi-processed feed items such as bran, oilcakes, meals, and molasses have been completely excluded from the calculations at all stages. It should be noted that when calculating indices of agricultural, food and nonfood production, all intermediate primary inputs of agricultural origin are deducted. However, for indices of any other commodity group, only inputs originating from within the same group are deducted; thus, only seed is removed from the group "crops" and from all crop subgroups, such as cereals, oil crops, etc.; and both feed and seed originating from within the livestock sector (e.g., milk feed, hatching eggs) are removed from the group "livestock products". For the main two livestock subgroups, namely, meat and milk, only feed originating from the respective subgroup is removed. Indices, which consider deductions for feed and seed, are referred to as "net". Indices calculated without any deductions for feed and seed are referred to as "gross". The "international commodity prices" are used to avoid the use of exchange rates for obtaining continental and world aggregates, and to improve and facilitate international comparative analysis of productivity at the national level. These" international prices," expressed in so-called "international dollars," are derived using a Geary-Khamis formula** for the agricultural sector. This method assigns a single "price" to each commodity. For example, one metric ton of wheat has the same price regardless of the country where it was

produced. The currency unit in which the prices are expressed has no influence on the indices published. The commodities covered in the computation of indices of agricultural production are all crops and livestock products originating in each country. Practically all products are covered, with the main exception of fodder crops.

Although South Africa's food production index increased in the first ten year following the year 2000, since then there is no significant shift (Figure 1.114). These figures are comparable to the other benchmark countries and are levelled with the World average (Figure 1.115).

** A Laspeyres Index is known as a "base-weighted" or "fixed-weighted" index because the price increases are weighted by the quantities in the base period. The Consumer Price Index is an example of a Laspeyres Index. http://www.usna.edu/Users/econ/rbrady/312%20Materials/LaspeyresCalc.pdf*
*** Geary-Khamis formula is an aggregation method in which category "international prices" (reflecting relative category values) and country purchasing power parities (PPPs), (depicting relative country price levels) are estimated simultaneously from a system of linear equations. http://stats.oecd.org/glossary/detail.asp?ID=5528*

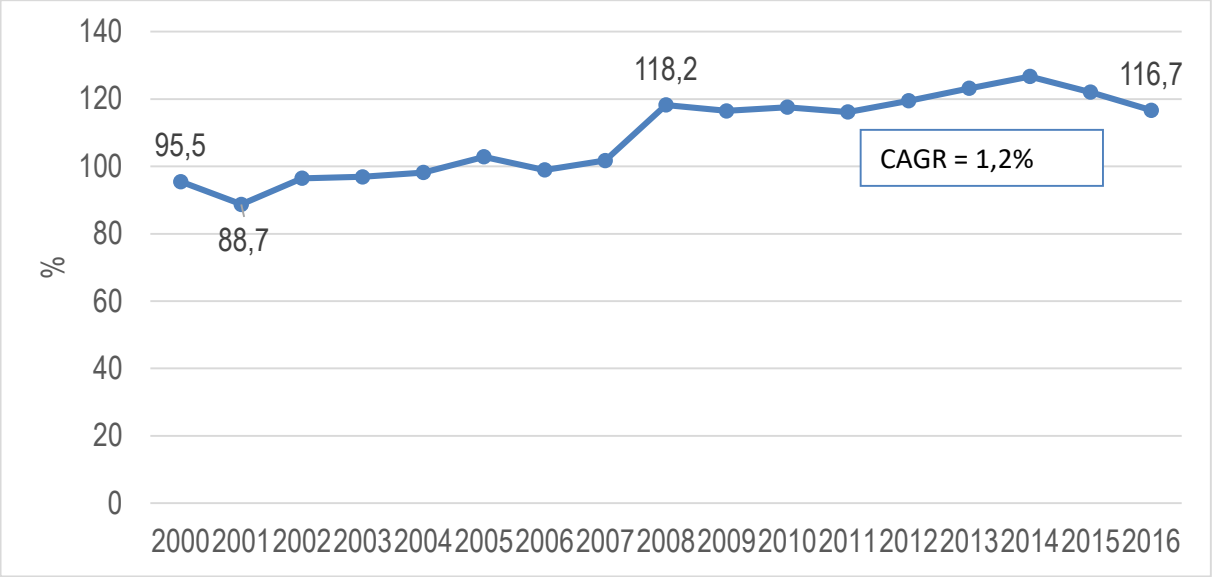

Figure 1.114. Food production index in South Africa (2004 – 2006 = 100%)

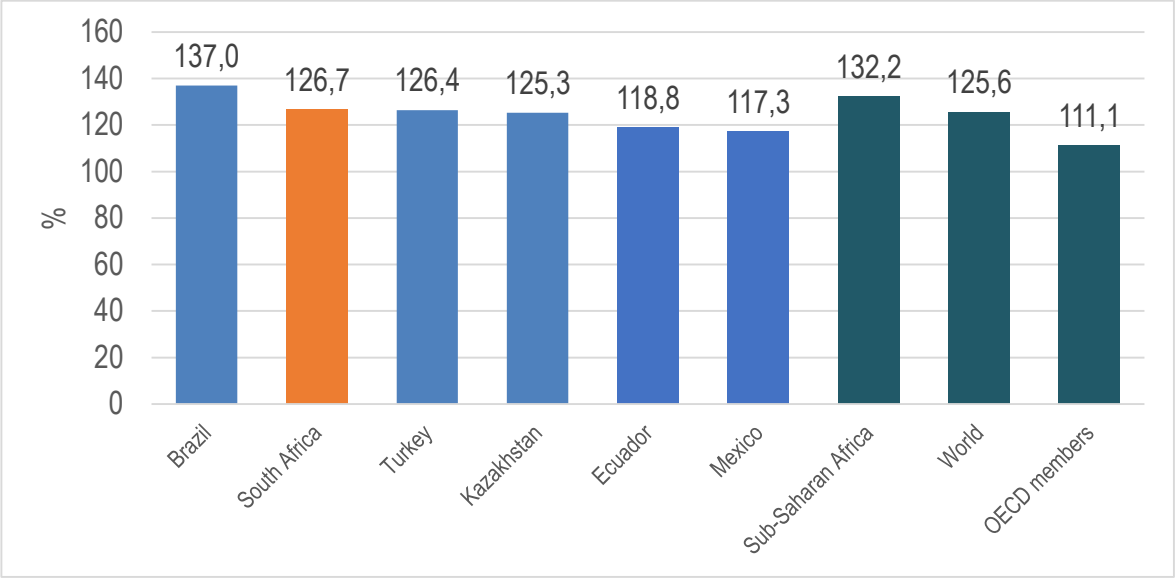

Figure 1.115. Food production index, 2014

1.10.2 Food exports (% of merchandise exports)

Food comprises the commodities in SITC sections 0 (food and live animals), 1 (beverages and tobacco), and 4 (animal and vegetable oils and fats) and SITC division 22 (oil seeds, oil nuts, and oil kernels).

The classification of commodity groups is based on the Standard International Trade Classification (SITC) revision 3.

Food exports in South Africa as percentage of total merchandise exports have fluctuated in the last twenty years between 6.6 to 11 per cent (Figure 1.116). Except Ecuador and Brazil, which are among the top food exporters, South Africa is closer to the World the Sub-Saharan Africa average (Figure 1.117).

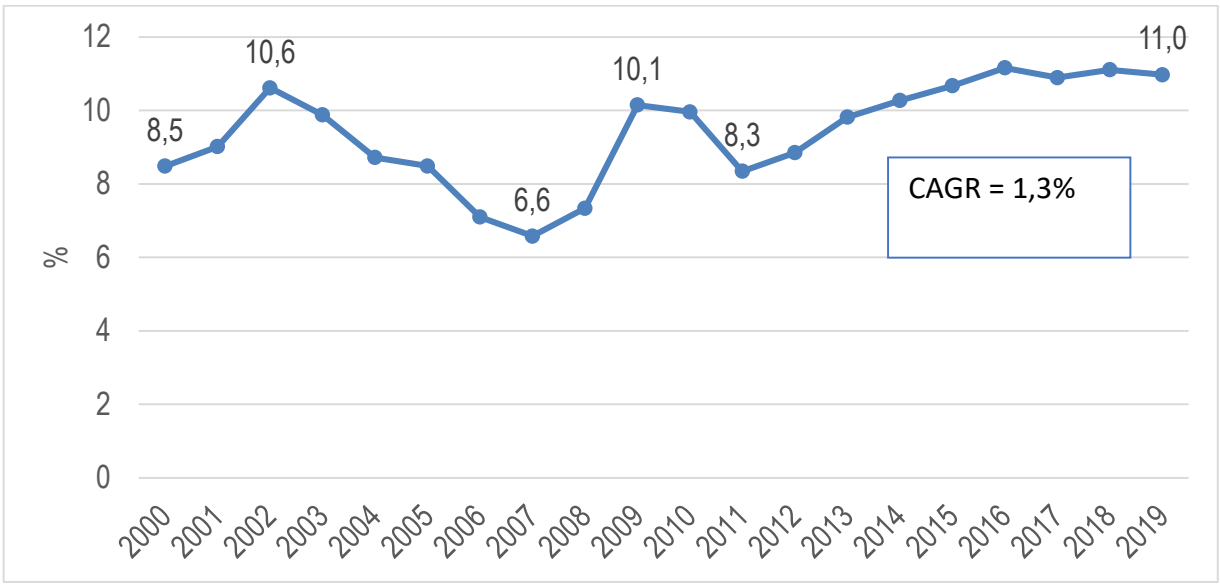

Figure 1.116. Food exports in South Africa

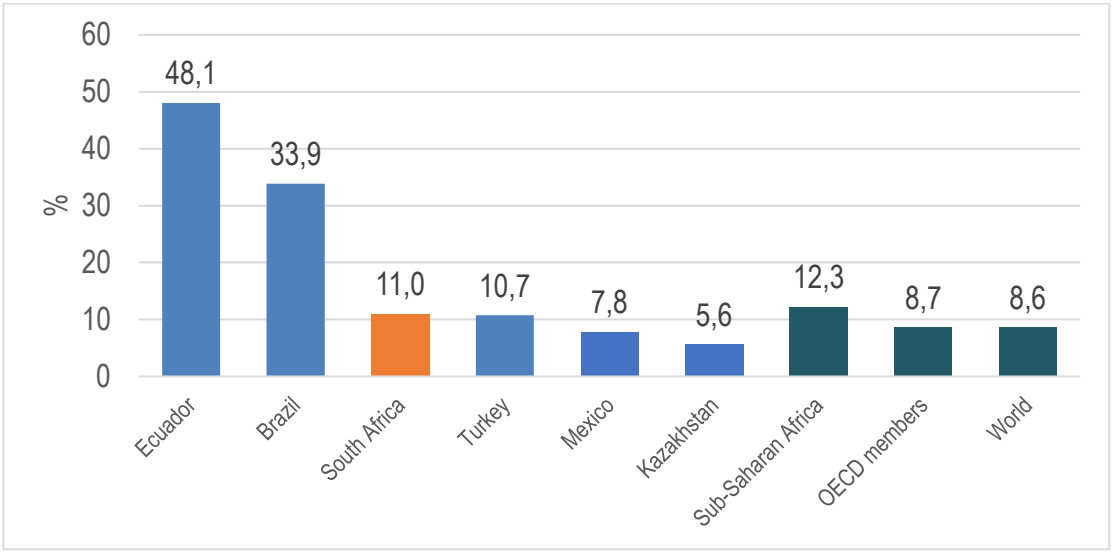

Figure 1.117. Food exports (% of merchandise exports), 2019

1.10.3 Low-birthweight babies (% of births)

Low-birthweight babies are newborns weighing less than 2,500 grams, with the measurement taken within the first hour of life, before significant postnatal weight loss has occurred.

Model methods are used based on availability of country input data. Country input data included: (i) estimates from administrative sources representing =90 per cent of live births labelled as high coverage; (ii) estimates from administrative sources representing 80 to <90 per cent of live births labelled as medium coverage; and (iii) estimates from household surveys adjusted for

missing birthweights and heaping. The model methods applied were b-spline: data for countries with =8 data points from high coverage administrative sources with =1 prior to 2005 and =1 more recent than 2010, were smoothed with b-spline regression to generate annual LBW prevalence estimates that followed country-reported estimates very closely. Hierarchical regression: data for countries not meeting requirements for b-spline but with =1 LBW country input data point was fitted into a model using a set of covariates to generate annual LBW prevalence estimates. The covariates included the natural log of neonatal mortality rate; the proportion of children underweight (weight for-age z score below minus two standard deviations from median weight for age of reference population); data type (high coverage administrative, low coverage administrative, household survey); UN region (e.g., Southern Asia, Caribbean); and a country-specific random effect.). These estimates may vary substantially from those reported by countries. Partial data: the estimate is based on only partial data for the most recent survey, therefore modelled estimates not shown for the individual country.

Traditionally low-birthweight has been a health problem in South Africa. Although some improvement has been observed in the last couple of decades, the figures are still high at 14.2 percent of the whole newborns (Figure 1.118). This figure is the highest among the benchmark countries and just below the World average (Figure 1.119).

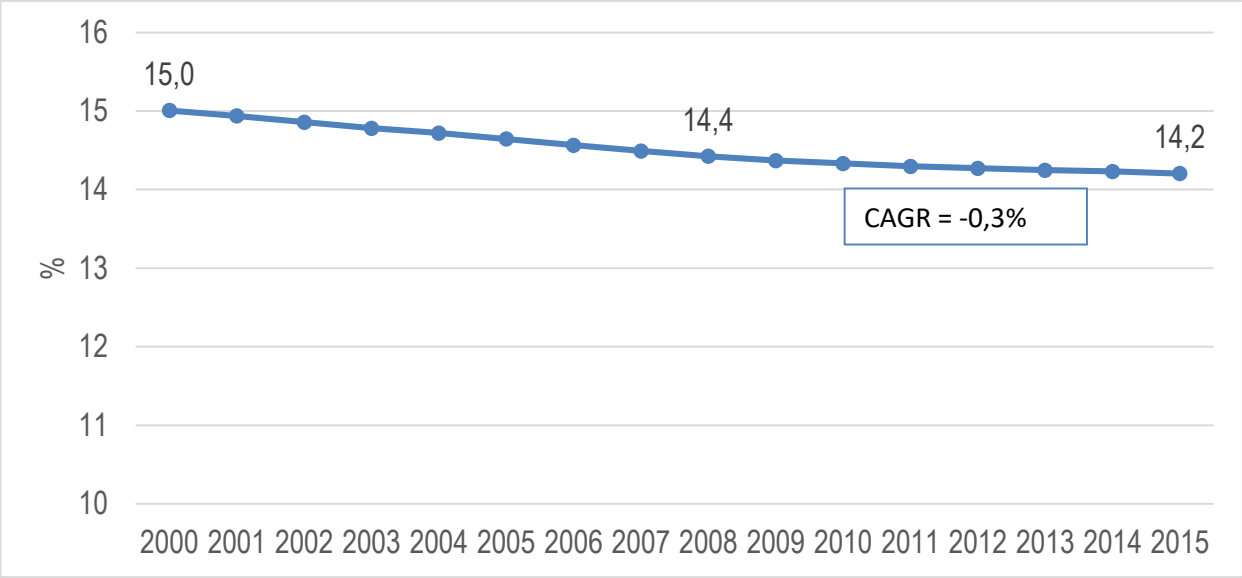

Figure 1.118. Low-birthweight babies in South Africa

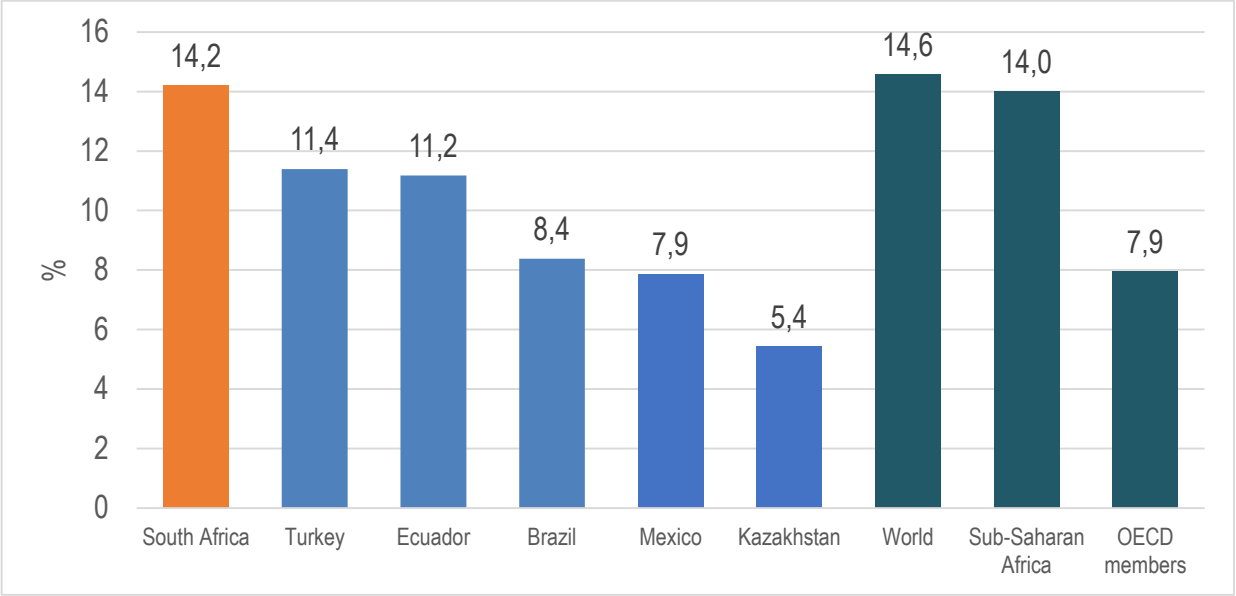

Figure 1.119. Low-birthweight babies (% of births), 2015

1.10.4 Prevalence of severe food insecurity in the population (%)

The percentage of people in the population who live in households classified as severely food insecure. A household is classified as severely food insecure when at least one adult in the household has reported to have been exposed, at times during the year, to several of the most severe experiences described in the FIES questions, such as to have been forced to reduce the quantity of the food, to have skipped meals, having gone hungry, or having to go for a whole day without eating because of a lack of money or other resources.

The assessment is conducted using data collected with the Food Insecurity Experience Scale or a compatible experience-based food security measurement questionnaire (such as the HFSSM). The probability to be food insecure is estimated using the one-parameter logistic Item Response Theory model (the Rasch model) and thresholds for classification are made cross-country comparable by calibrating the metrics obtained in each country against the FIES global reference scale, maintained by FAO. The threshold to classify "severe" food insecurity corresponds to the severity associated with the item "having not eaten for an entire day" on the global FIES scale. It is an indicator of lack of food access. The indicator is calculated as an average over 3 years (e.g., data for 2015 is the average of 2014-2016 data).

Although Figure 1.120 shows severe food security in South Africa has been 18 per cent, and then reduced to zero this data should be considered with caution (Figure 1.120). Similarly, no data seems to be available for for benchmarking with other countries (Figure 1.121).

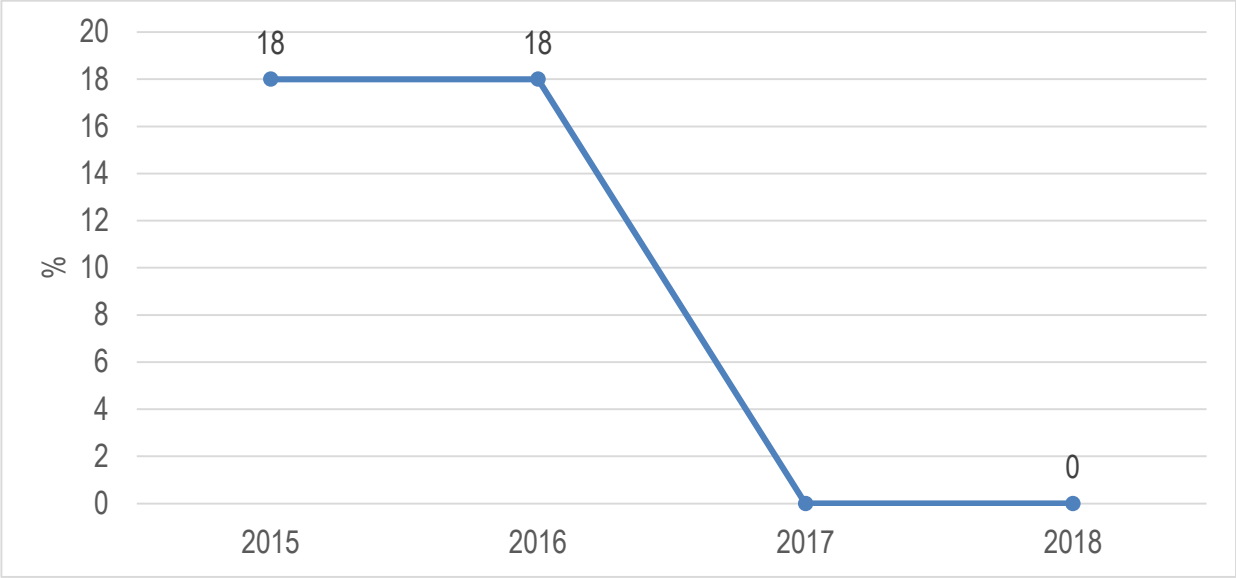

Figure 1.120. Prevalence of severe food insecurity in South Africa

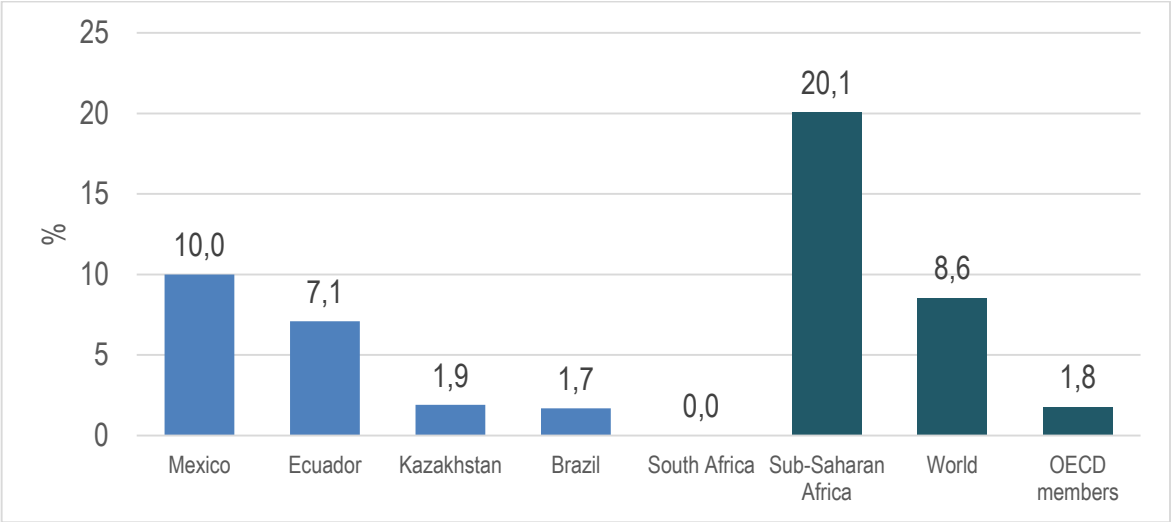

Figure 1.121. Prevalence of severe food insecurity in the population, 2017

1.10.5 Prevalence of undernourishment (% of population)

Population below minimum level of dietary energy consumption (also referred to as prevalence of undernourishment) shows the percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously. Data showing as 5 may signify a prevalence of undernourishment below 5%.

Data on undernourishment are from the Food and Agriculture Organization (FAO) of the United Nations and measure food deprivation based on average food available for human

consumption per person, the level of inequality in access to food, and the minimum calories required for an average person.

Undernourishment or insufficient food intake is an important problem in South Africa. Data shows that the prevalence of undernourishment is growing in South Africa reaching to 5.7 per cent of the total population (Figure 1.122). Although South Africa is performing better compared to the other Sub-Saharan African countries, and the World average, there is sill more to be done to reduce insufficient food intake, which appears to be in growth in recent years (Figure 1.123).

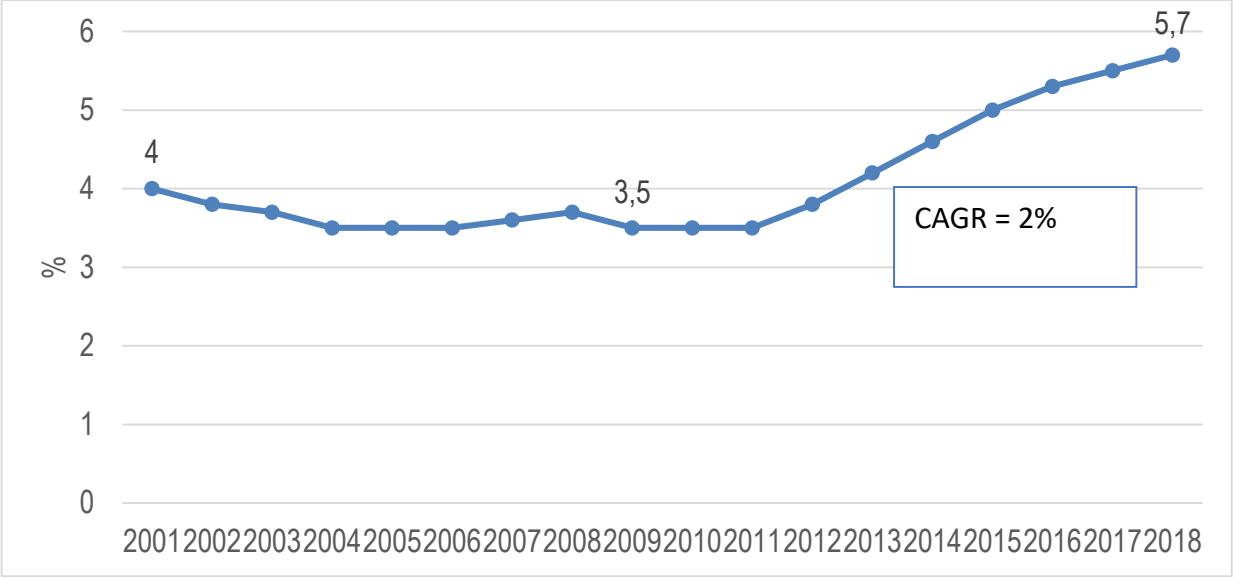

Figure 1.122. Prevalence of undernourishment in South Africa

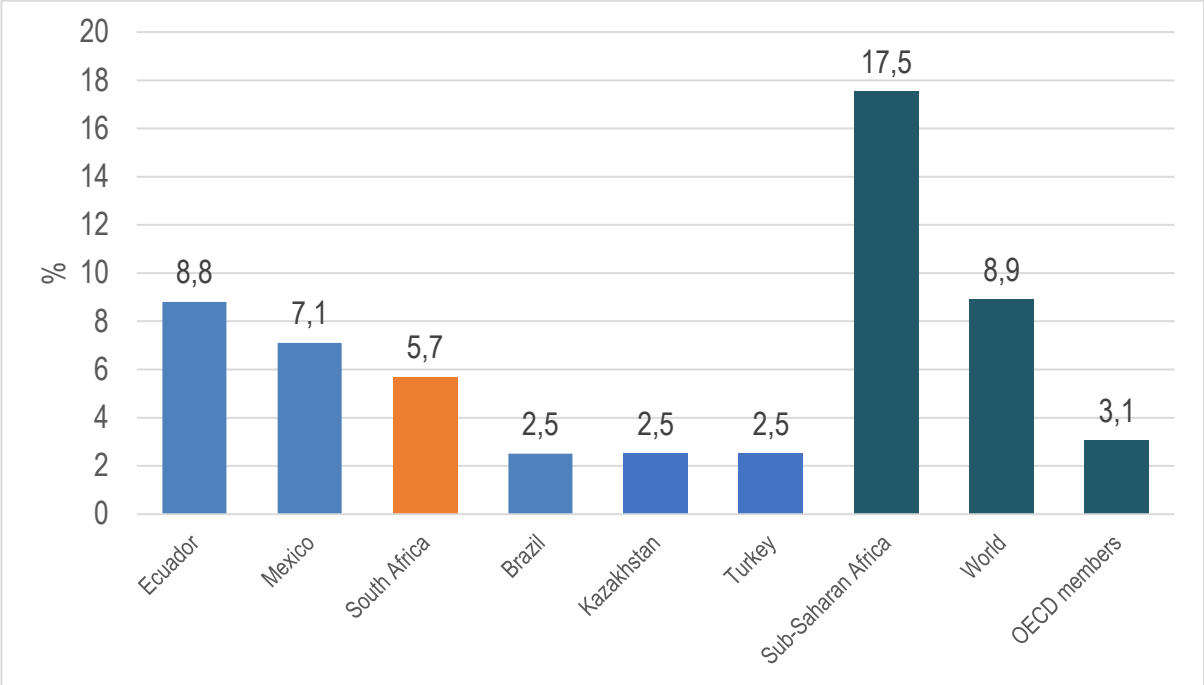

Figure 1.123. Prevalence of undernourishment, 2018

1.10.6 Vitamin A supplementation coverage rate (% of children ages 6-59 months)

Vitamin A supplementation refers to the percentage of children ages 6-59 months old who received at least two doses of vitamin A in the previous year.

Vitamin A is essential for optimal functioning of the immune system. Vitamin A deficiency, a leading cause of blindness, also causes a greater risk of dying from a range of childhood ailments such as measles, malaria, and diarrhea. In low- and middle-income countries, where vitamin A is consumed largely in fruits and vegetables, daily per capita intake is often insufficient to meet dietary requirements. Providing young children with two high-dose vitamin A capsules a year is a safe, cost-effective, efficient strategy for eliminating vitamin A deficiency and improving child survival. Giving vitamin A to new breastfeeding mothers helps protect their children during the first few months of life. Food fortification with vitamin A is being introduced in many developing countries.

Vitamin A supplementation rate is almost 50 per cent in South Africa, which means that half of the children aged 6 to 59 months do not receive sufficient vitamin (Figure 1.124). Although this figure is slightly below the World and the Sub-Saharan African average, it is still extremely high (Figure 1.125).

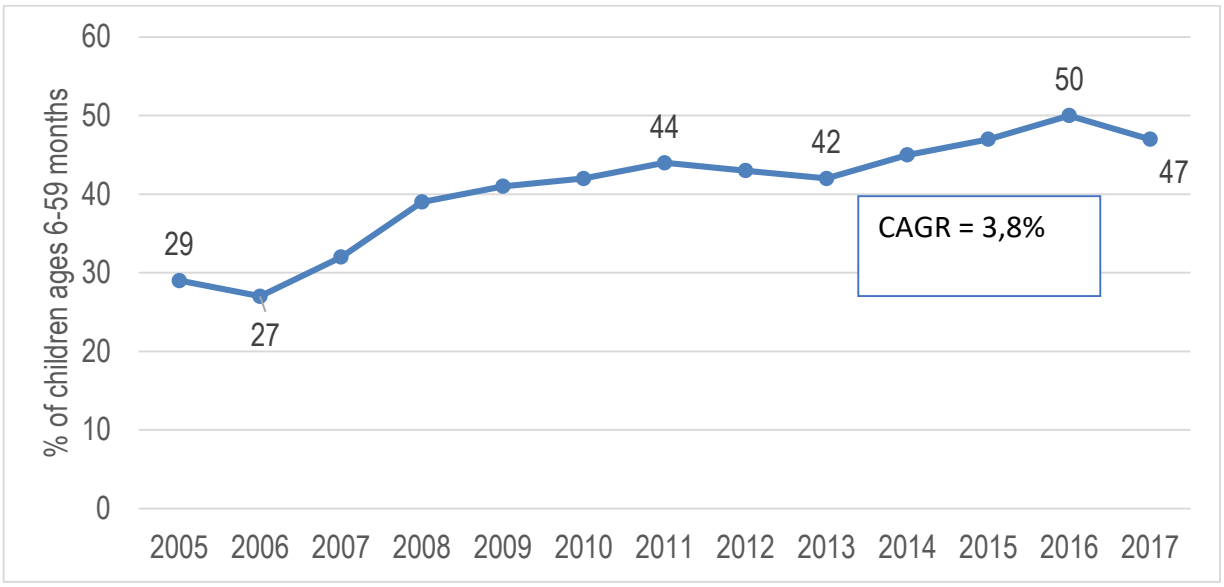

Figure 1.124. Vitamin A supplementation coverage rate in South Africa

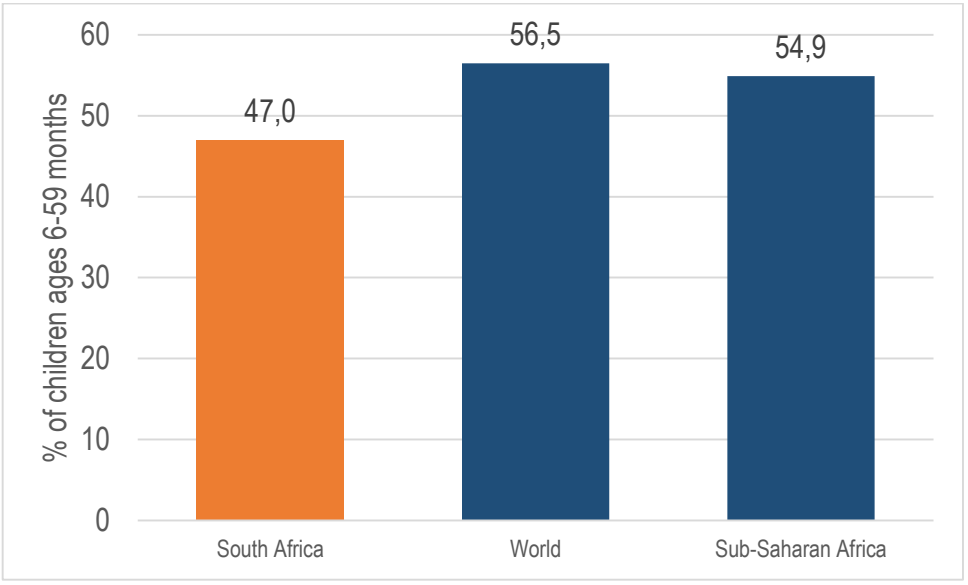

Figure 1.125. Vitamin A supplementation coverage rate, 2017

1.10.7 Normalized indicators values and composite index for the «Affordable food» factor

In terms of joint affordable food index, South Africa is above average, but there is still more to be done to provide sufficient and good quality food to the population of the country (Figure 1.126).

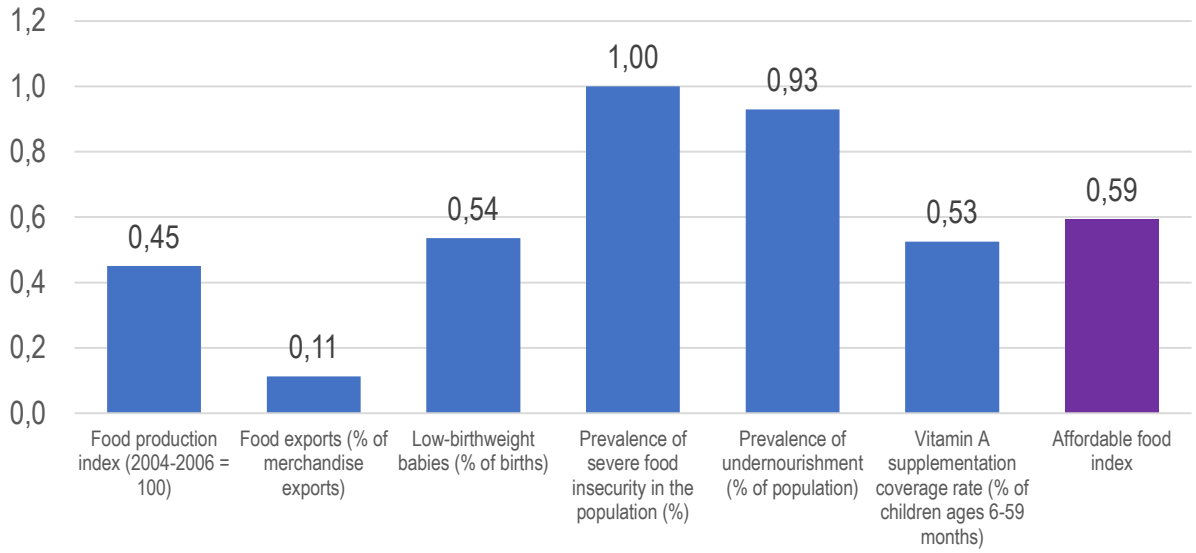

Figure 1.126. Normalized indicators values and a composite index for the «Affordable food» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

1.11 Low greenhouse gas emission

1.11.1 Other greenhouse gas emissions (% change from 1990)

Other greenhouse gas emissions are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Each year of data shows the percentage change to that year from 1990.

Other greenhouse gas emissions are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (F-gases (c-C4F8 GWP=8700, C2F6 GWP=9200, C3F8 GWP=7000, C4F10 GWP=7000, C5F12 GWP=7500, C6F14 GWP=7400, C7F16 GWP=7820, CF4 GWP=6500, HFC-125 GWP=2800, HFC-134a GWP=1300, HFC-143a GWP=3800, HFC-152a GWP=140, HFC-227ea GWP=2900, HFC-23 GWP=11700, HFC-236fa GWP=6300, HFC-245fa GWP=858, HFC-32 GWP=650, HFC-365mfc GWP=804, HFC-43-10-mee GWP=1300, SF6 GWP=23900). Derived as residuals from total GHG emissions, CO2 emissions, CH4 emissions, and N2O emissions in kt of CO equivalent. Other greenhouse gases covered under the Kyoto Protocol are hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Although emissions of these artificial gases are small, they are more powerful greenhouse gases than carbon dioxide, with much higher atmospheric lifetimes and high global warming potential. The emissions are usually expressed in carbon dioxide equivalents using the global warming potential, which allows the effective contributions of different gases to be compared.

Other greenhouse gas emissions have increased substantially in South Africa, almost nine folds with the 1990 levels. Last few years have been stable at this rate (Figure 1.127). Compared to the other countries these figures are extremely high, nearly five times more than the closest country (Figure 1.128).

Source: World Bank staff estimates from original source: European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR): http://edgar.jrc.ec.europa.eu/.

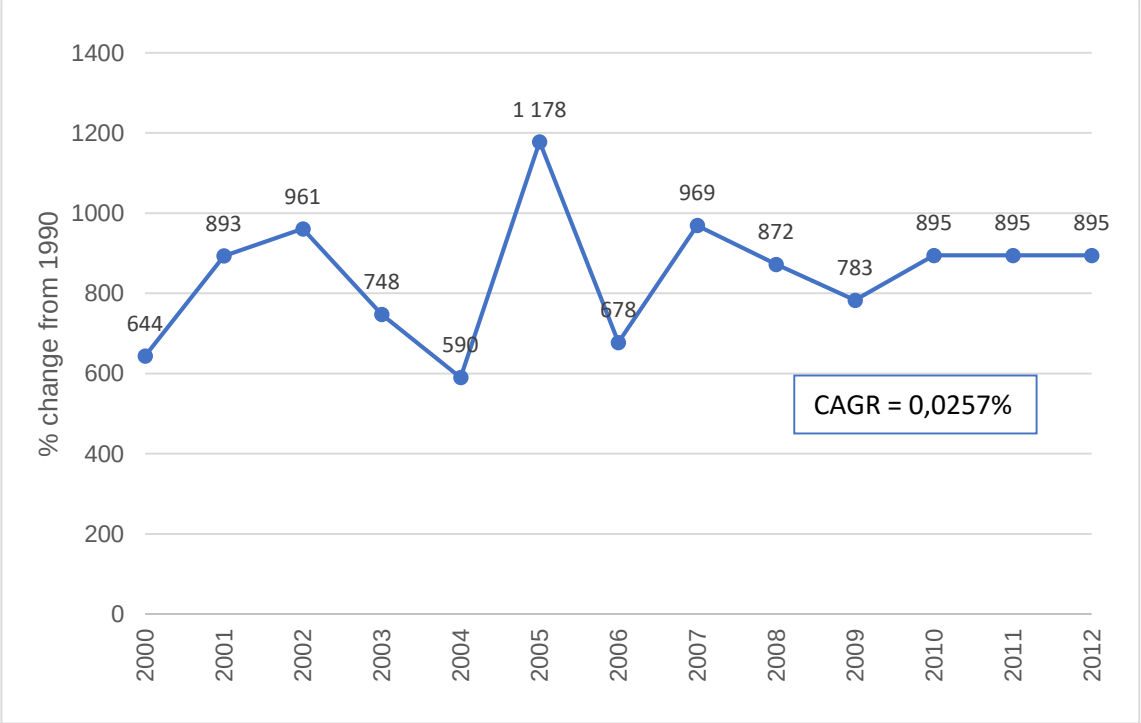

Figure 1.127. Other greenhouse gas emission in South Africa

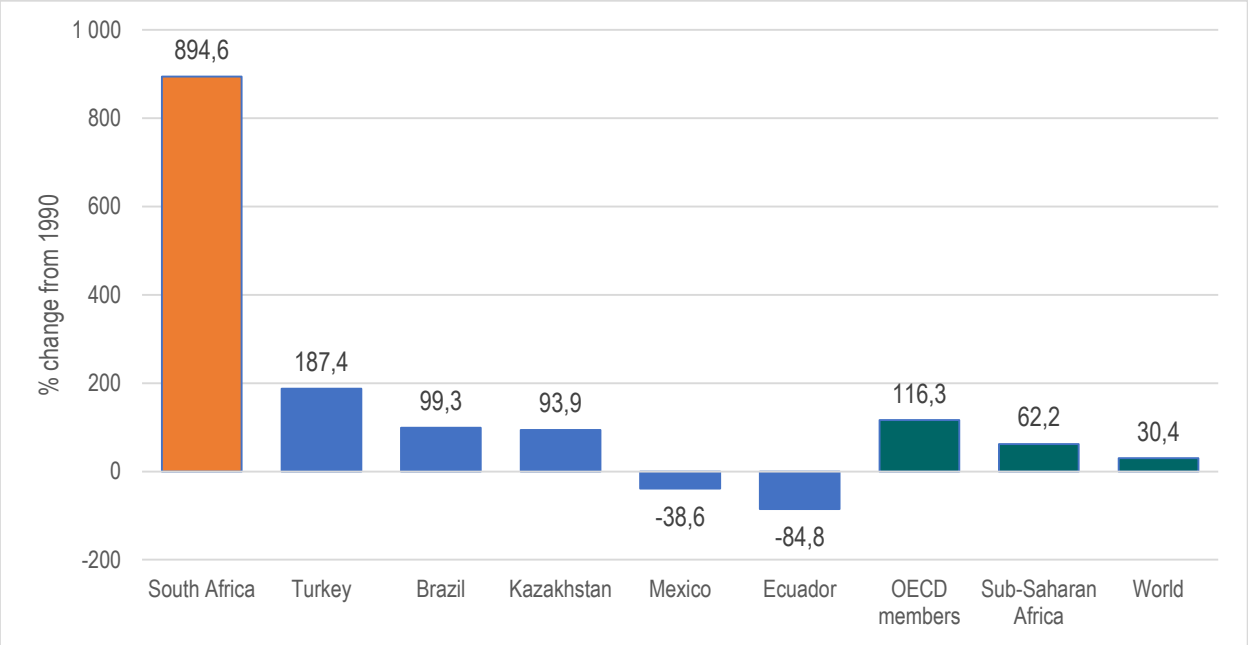

Figure 1.128. Other greenhouse gas emission, 2012

1.11.2 Other greenhouse gas emissions, HFC, PFC and SF6 (metric tons of CO2 equivalent per capita)

Other greenhouse gas emissions are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Other greenhouse gas emissions are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (F-gases (c-C4F8 GWP=8700, C2F6 GWP=9200, C3F8 GWP=7000, C4F10 GWP=7000, C5F12 GWP=7500, C6F14 GWP=7400, C7F16 GWP=7820, CF4 GWP=6500, HFC-125 GWP=2800, HFC-134a GWP=1300, HFC-143a GWP=3800, HFC-152a GWP=140, HFC-227ea GWP=2900, HFC-23 GWP=11700, HFC-236fa GWP=6300, HFC-245fa GWP=858, HFC-32 GWP=650, HFC-365mfc GWP=804, HFC-43-10-mee GWP=1300, SF6 GWP=23900). Derived as residuals from total GHG emissions, CO2 emissions, CH4 emissions, and N2O emissions in kt of CO equivalent. Other greenhouse gases covered under the Kyoto Protocol are hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Although emissions of these artificial gases are small, they are more powerful greenhouse gases than carbon dioxide, with much higher atmospheric lifetimes and high global warming potential. The emissions are usually expressed in carbon dioxide equivalents using the global warming potential, which allows the effective contributions of different gases to be compared.

Other greenhouse gas emissions in terms of by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride have shown a decline in recent years and are relatively low compared to the other countries (Figure 1.129 & 1.130).

Source: World Bank staff estimates from original source: European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR): http://edgar.jrc.ec.europa.eu/.

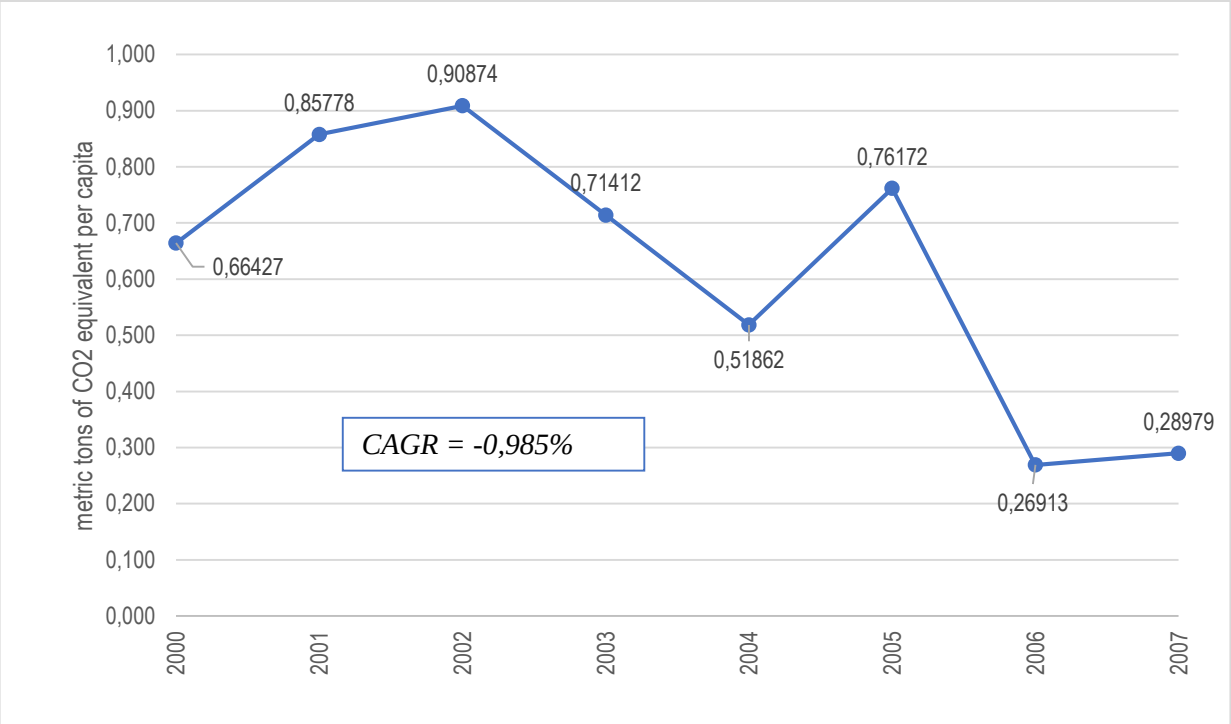

Figure 1.129. Other greenhouse gas emissions, HFC, PFC and SF6 in South Africa

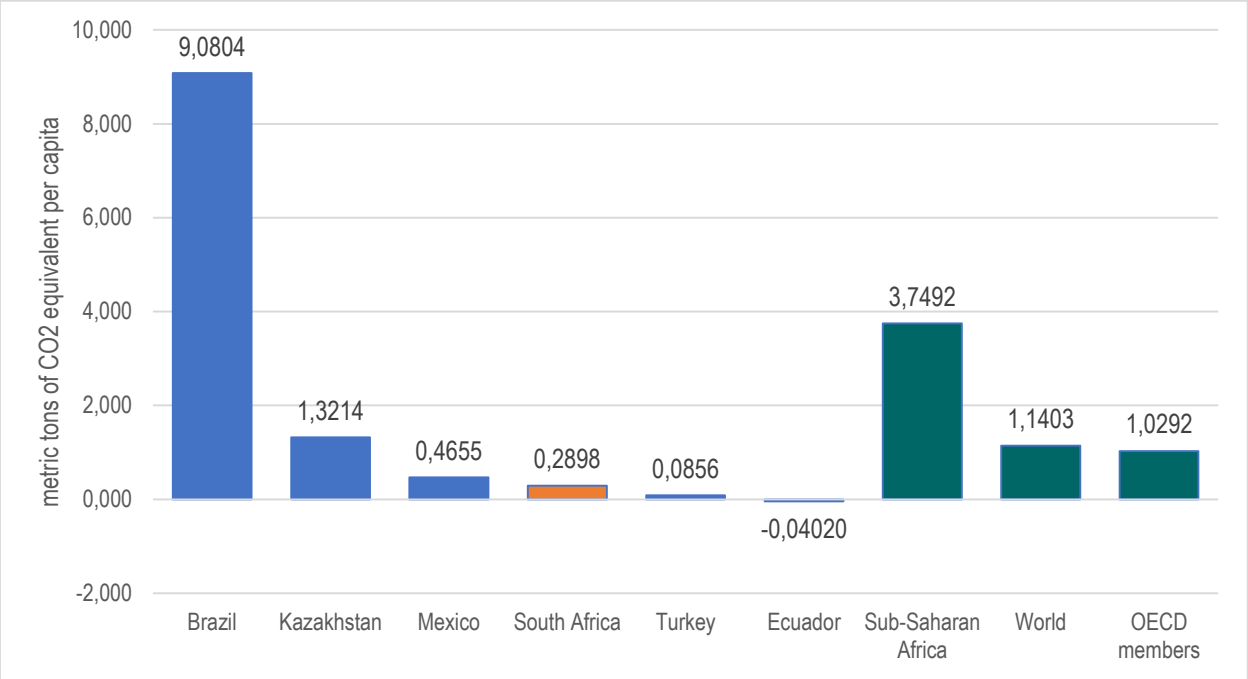

Figure 1.130. Other greenhouse gas emissions, HFC, PFC and SF6 (metric tons of CO2 equivalent per capita), 2007

1.11.3 Total greenhouse gas emissions (% change from 1990)

Total greenhouse gas emissions are composed of CO2 totals excluding short-cycle biomass burning (such as agricultural waste burning and savanna burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6). Each year of data shows the percentage change to that year from 1990.

The GHG totals are expressed in CO2 equivalent using the GWP100 metric of the Second Assessment Report of IPCC and include CO2 (GWP100=1), CH4 (GWP100=21), N2O (GWP100=310) and F-gases (c-C4F8 GWP=8700, C2F6 GWP=9200, C3F8 GWP=7000, C4F10 GWP=7000, C5F12 GWP=7500, C6F14 GWP=7400, C7F16 GWP=7820, CF4 GWP=6500, HFC-125 GWP=2800, HFC-134a GWP=1300, HFC-143a GWP=3800, HFC-152a GWP=140, HFC-227ea GWP=2900, HFC-23 GWP=11700, HFC-236fa GWP=6300, HFC-245fa GWP=858, HFC-32 GWP=650, HFC-365mfc GWP=804, HFC-43-10-mee GWP=1300, SF6 GWP=23900).

Looking at the total greenhouse gas emissions, it is seen that the level of emissions has increased 43.79 per cent compared to the 1990 (Figure 1.131). With this figure, South Africa is relatively better positioned compared to the other benchmark countries, but is still higher than the World average (Figure 1.132).

Source: World Bank staff estimates from original source: European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR): http://edgar.jrc.ec.europa.eu/.

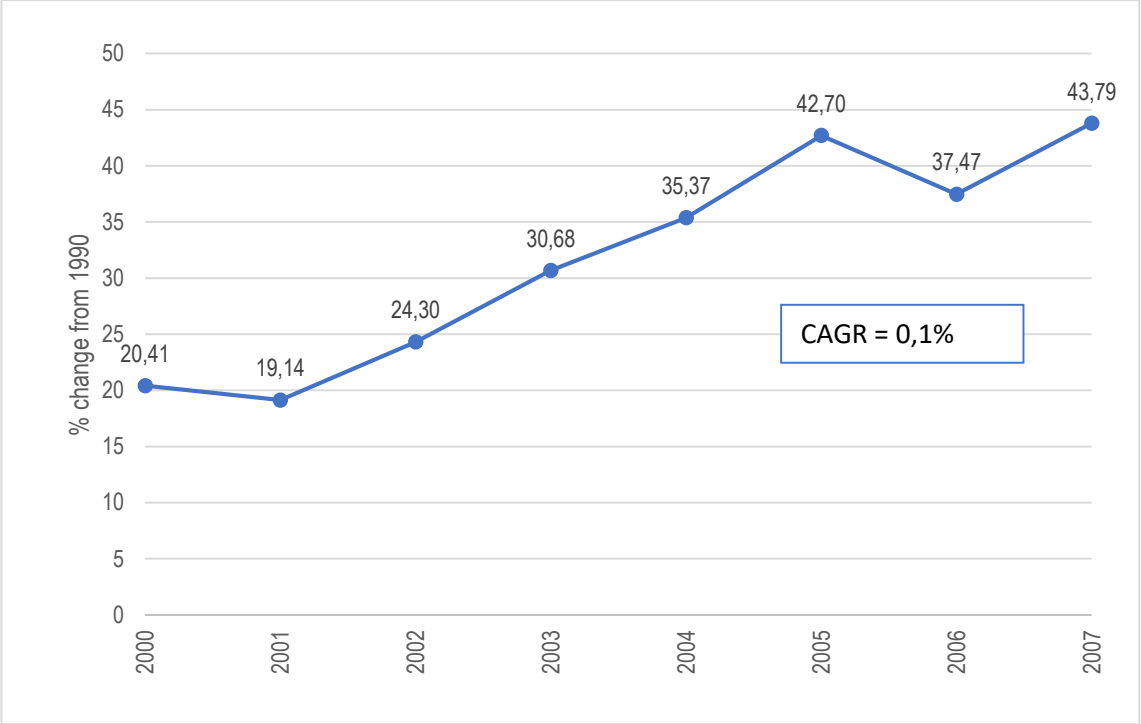

Figure 1.131. Total greenhouse gas emissions in South Africa

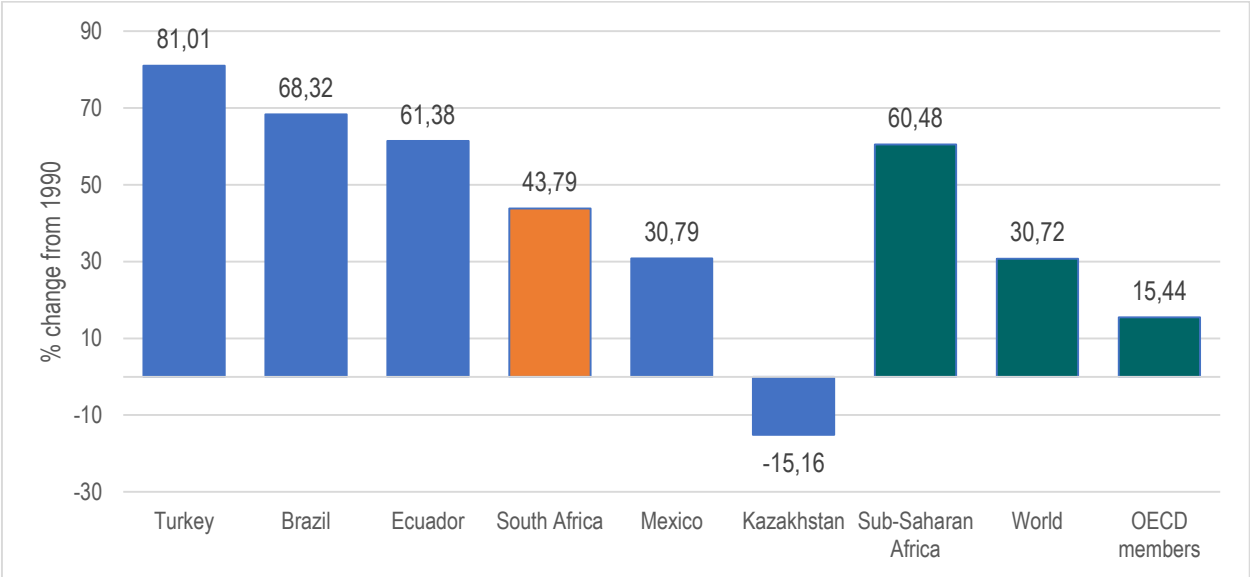

Figure 1.132. Total greenhouse gas emissions (% change from 1990), 2007

1.11.4 Total greenhouse gas emissions (kt of CO2 equivalent per 1000 population)

Total greenhouse gas emissions in kt of CO2 equivalent are composed of CO2 totals excluding short-cycle biomass burning (such as agricultural waste burning and savanna burning)

but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH4 sources, N2O sources and F-gases (HFCs, PFCs and SF6).

The GHG totals are expressed in CO2 equivalent using the GWP100 metric of the Second Assessment Report of IPCC and include CO2 (GWP100=1), CH4 (GWP100=21), N2O (GWP100=310) and F-gases (c-C4F8 GWP=8700, C2F6 GWP=9200, C3F8 GWP=7000, C4F10 GWP=7000, C5F12 GWP=7500, C6F14 GWP=7400, C7F16 GWP=7820, CF4 GWP=6500, HFC-125 GWP=2800, HFC-134a GWP=1300, HFC-143a GWP=3800, HFC-152a GWP=140, HFC-227ea GWP=2900, HFC-23 GWP=11700, HFC-236fa GWP=6300, HFC-245fa GWP=858, HFC-32 GWP=650, HFC-365mfc GWP=804, HFC-43-10-mee GWP=1300, SF6 GWP=23900).

Similarly total greenhouse gas emissions in terms od kt of CO2 equivalent per 1000 population have been in increase since 2000. Average emission figures are comperable to the other countries of benchmark (Figure 1.133 & 1.134).

Source: European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR), EDGARv4.2 FT2012: http://edgar.jrc.ec.europa.eu/

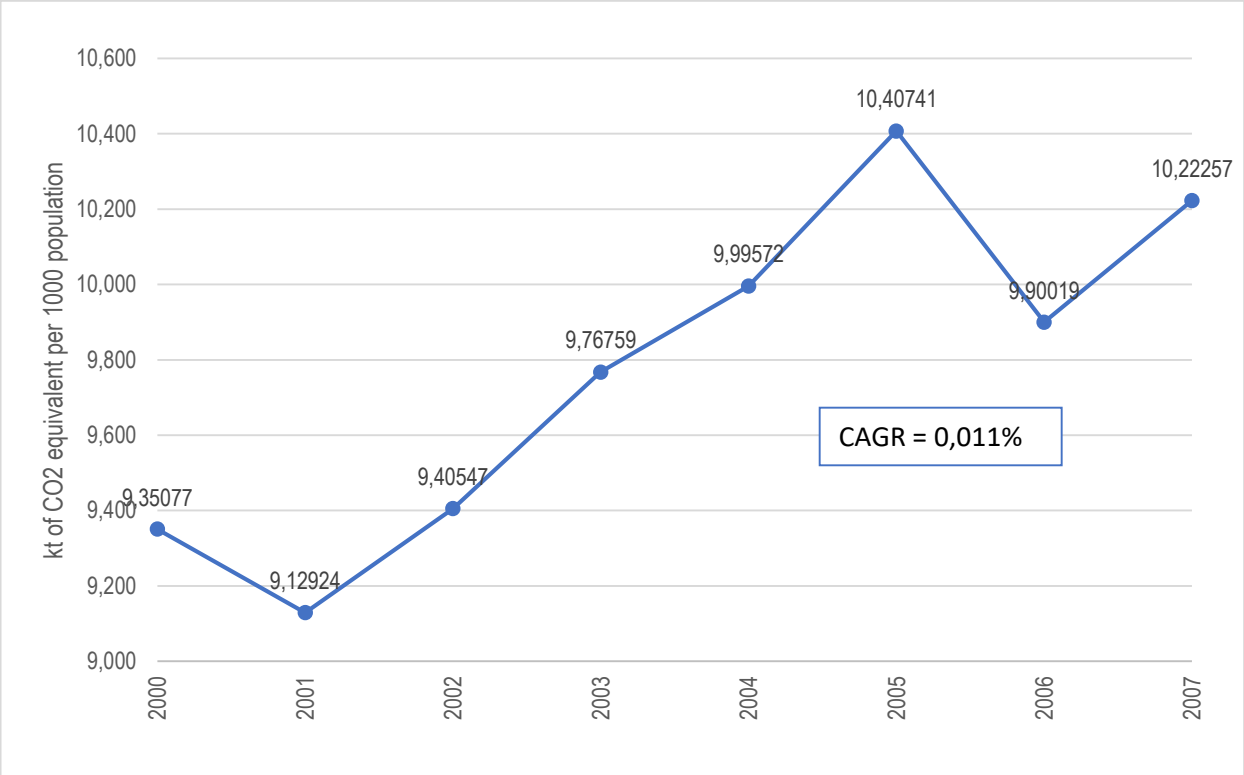

Figure 1.133. Total greenhouse gas emissions of South Africa

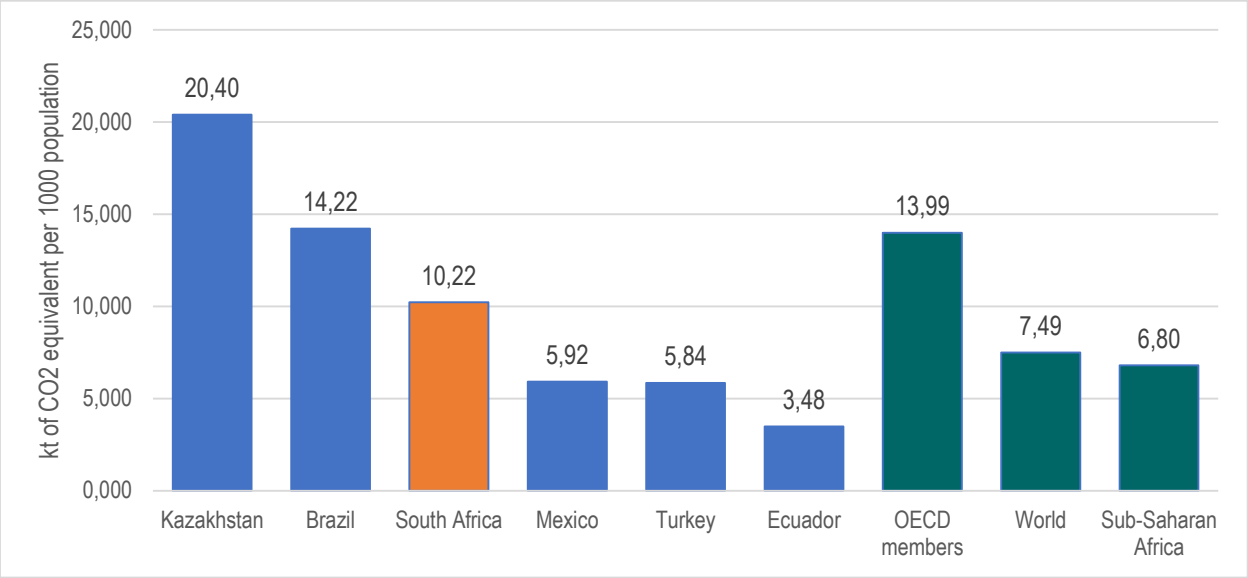

Figure 1.134. Total greenhouse gas emissions (kt of CO2 equivalent per 1000 population), 2007

1.11.5 Normalized indicators values and composite index for the «Low greenhouse gas emission» factor

Finally, data shows that South Africa is relatively better positioned considering the low greenhouse emission index (Figure 1.135). However, there is still more to do in order to reduce the emissions for cleaner environment.

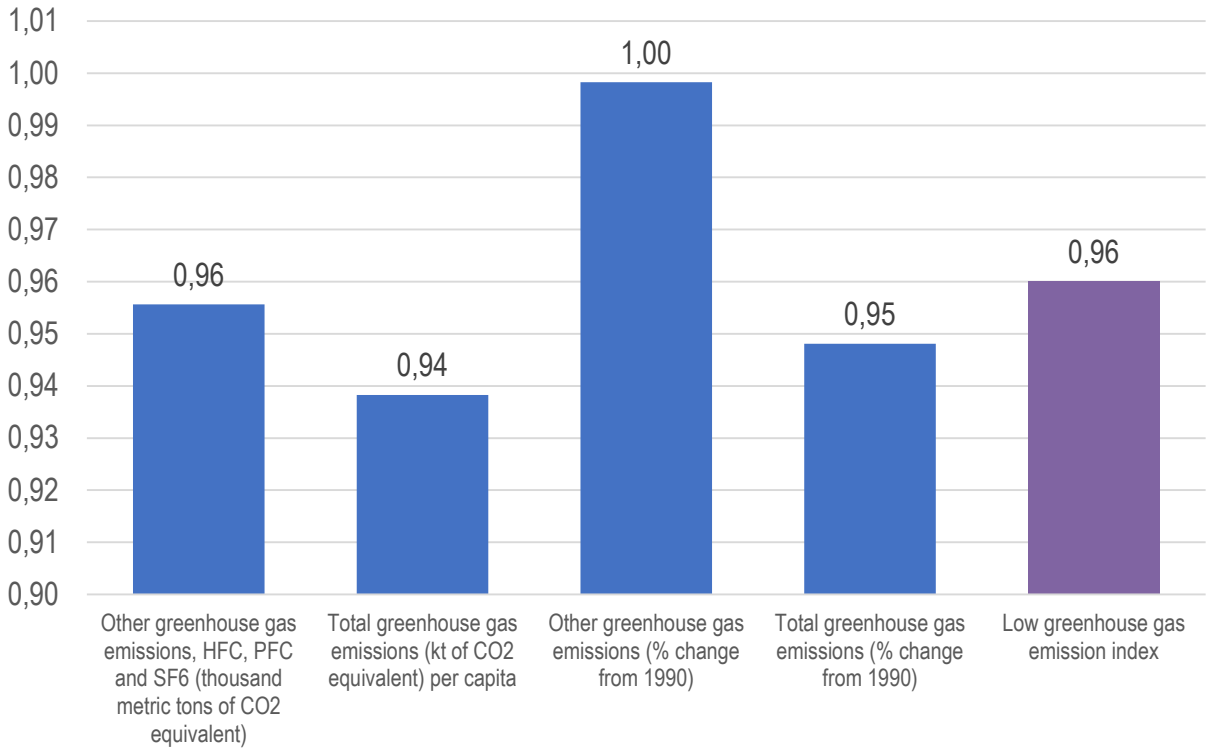

Figure 1.135. Normalized indicators values and a composite index for the «Low greenhouse gas emission» factor (0 = worst value among the analyzed countries; 1 = best value among the analyzed countries)

2 SEMANTIC ANALYSIS

The semantic analysis was performed on the basis of the system of Intelligent Foresight Analytics (iFORA), developed by ISSEK HSE, which combines more than 400 million unstructured documents, including scientific papers/books, research grants, patents, analytical reports, as well as publications of the world's largest news outlets (e.g. The New York Times, Express, The Independent among the others) and the largest news outlets with South African coverage (e.g. African Business, New African Magazine, Africa Launch Pad among the others). The study was conducted based on the analysis of news publications for 2010-2020. Scientific publications of South Africa were analysed through a scientometric analysis. The results of the semantic analysis in each area in presented in the chapter three of the present report.

The iFORA system works based on a supercomputer and a powerful data cluster, uses advanced data analysis methods, such as word2vec and Bidirectional Encoder Representations from Transformers (BERT) language models. The main products of iFORA are semantic maps, trend maps and matrices.

The semantic analysis was performed around **4 areas** that have been selected for developing **possible missions/priorities**:

- Circular economy/climate change.
- Health innovation.
- Education for the future and the future of society.
- High-tech industrialisation.

and terms relevant to 12 possible indicators/elements:

- Economic growth.
- Job creation.
- High quality health care services.
- High living standard.
- Access and supply of clean water.
- Affordable food.
- Carbon emission reduction.
- Low greenhouse gas emission.
- Export growth and competitiveness.

- Skills development.
- Renewable energy growth.
- Poverty alleviation.

For each of 4 areas (missions/priorities), one can find below key clusters identified in the framework of semantic analysis, semantic maps, and trend maps (both for each area total and for each cluster) and matrices that show the links between the four areas (clusters) and 12 indicators mentioned above.

The semantic maps given below represent the current appearance of the studied areas. Certain trends, technologies and other factors that determine the development of the areas are indicated by colored circular icons with captions. The most significant (central) of them are highlighted on the maps in large print. Groups of thematically closely connected topics are displayed in one color and form one cluster. The stronger the relationship between topics, the closer they are to each other on the semantic maps.

Centrality for sizes of terms is like centrality in graph theory and shows the most important terms that are maximally related to the rest of the terms. We used centrality based on word2vec model. To make it clear, synonyms can show a centrality of 0.8-0.9. Centrality of 0.1 between two terms means that the terms are not related and are rarely used in the same context. Centrality is indicated in legends for semantic maps, trend maps, and cluster maps.

The names of the clusters of semantic maps are given automatically by three terms of the cluster that are most often found in the analyzed documents.

Trend maps reflect the dynamics of the development of the studied trends. They are formed based on indicators of the significance and dynamics of the development of trends, technologies and other factors presented on the semantic maps, and provide their grouping into four quadrants. The upper right quadrant covers the most significant and dynamically developing trends, they are characterized by a high frequency and steady growth of mentions in documents.

Matrices show the connection between the analyzed topics, which is determined by co-occurrence of topics in documents. The larger the circle, the more often the analyzed topics appear in the same documents.

The study presents two main types of matrices:

– matrices, that show the co-occurrence in the analyzed documents of terms (keywords) relevant to 4 areas (possible missions/priorities) and terms relevant to 12 possible indicators/elements.
– matrices, that show the co-occurrence in the analyzed documents of terms relevant to clusters of 4 areas that have been selected for developing possible missions/priorities and terms relevant to 12 possible indicators/elements.

The co-occurrence number is indicated in the matrix legends. For each type of analysis, two matrices were constructed: matrices that show co-occurrence in all documents globally and co-occurrence in documents that mention South Africa. Figure 2.1 presents the global representation of the four areas and 12 indicators.

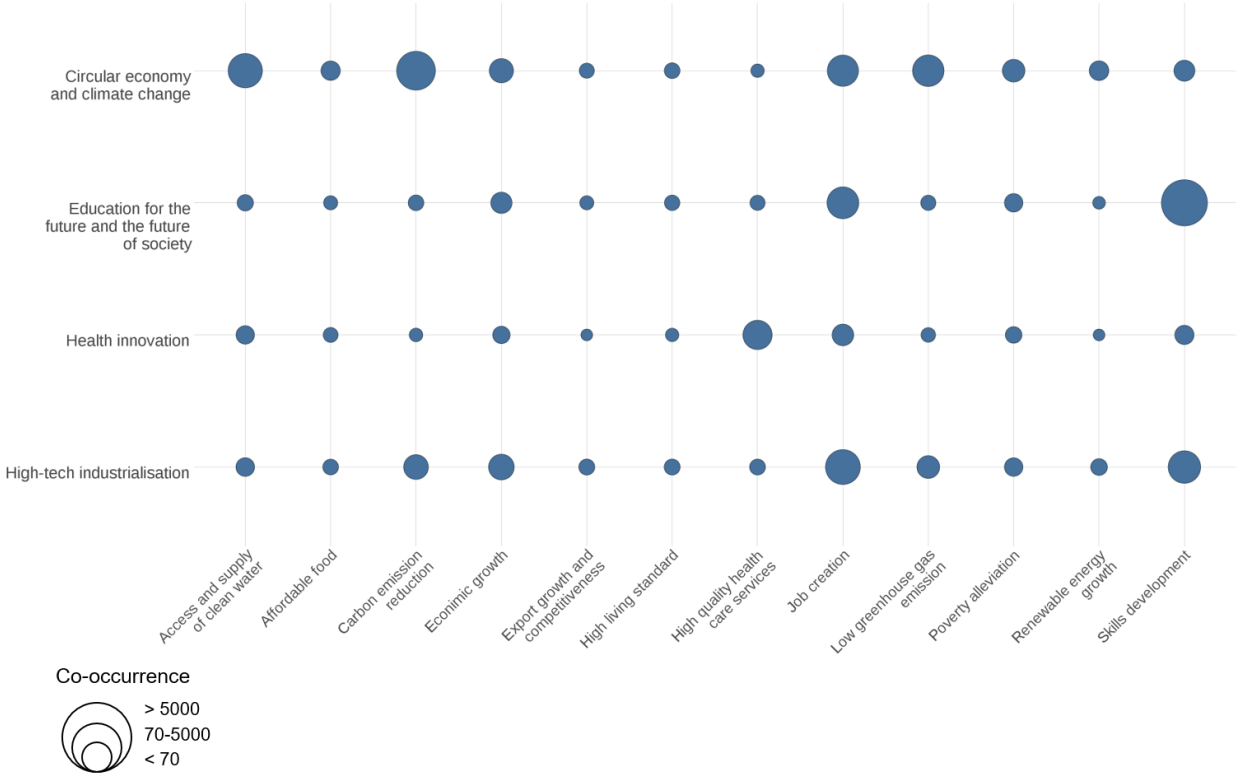

Figure 2.1. Matrix: 4 priorities and 12 indicators (in all documents)

The matrix, built on the analysis of all documents globally, shows that:

– Education for the future and the future of society are strongly linked for the development of future skills
– Circular economy and climate change area will require progress in carbon emission reduction

- Circular economy and climate change are also cloasely related to access and supply of clean water.
- High-tech industrialisation is also closely related to skills development and creation of new jobs.

The priority with the greatest connection with most indicators is circular economy/climate change. The most important indicators appear to be skills development and bob creation.

Figure 2.2 presents the same analysis specific to South Africa. The results of the global picture and South Africa match to a large extent. Circular economy and climate change appear as the most highly referred topics. They are pretty much connected with the priority areas of South Africa in relation to access and supply of clean water, carbon emission reduction and low greenhouse gas emission. Particularly the shift to circular economy imply new economic principles. Therefore, the concepts highly linked to economic growth, job creation, poverty alleviation and development of new skills for the new economy. Education for the future and future of economy should also address the priorities for skills development and job creating, which will be the drivers of the economic growth. High-tech industrialisation is also a driver of economic development and requires new skills and jobs to be created. Healthcare innovation is directly linked to the provision of high quality healthcare services, which is also linked to economic growth and access to clean water, which appears to be one of the areas for development in South Africa as discussed in earlier statistical analysis.

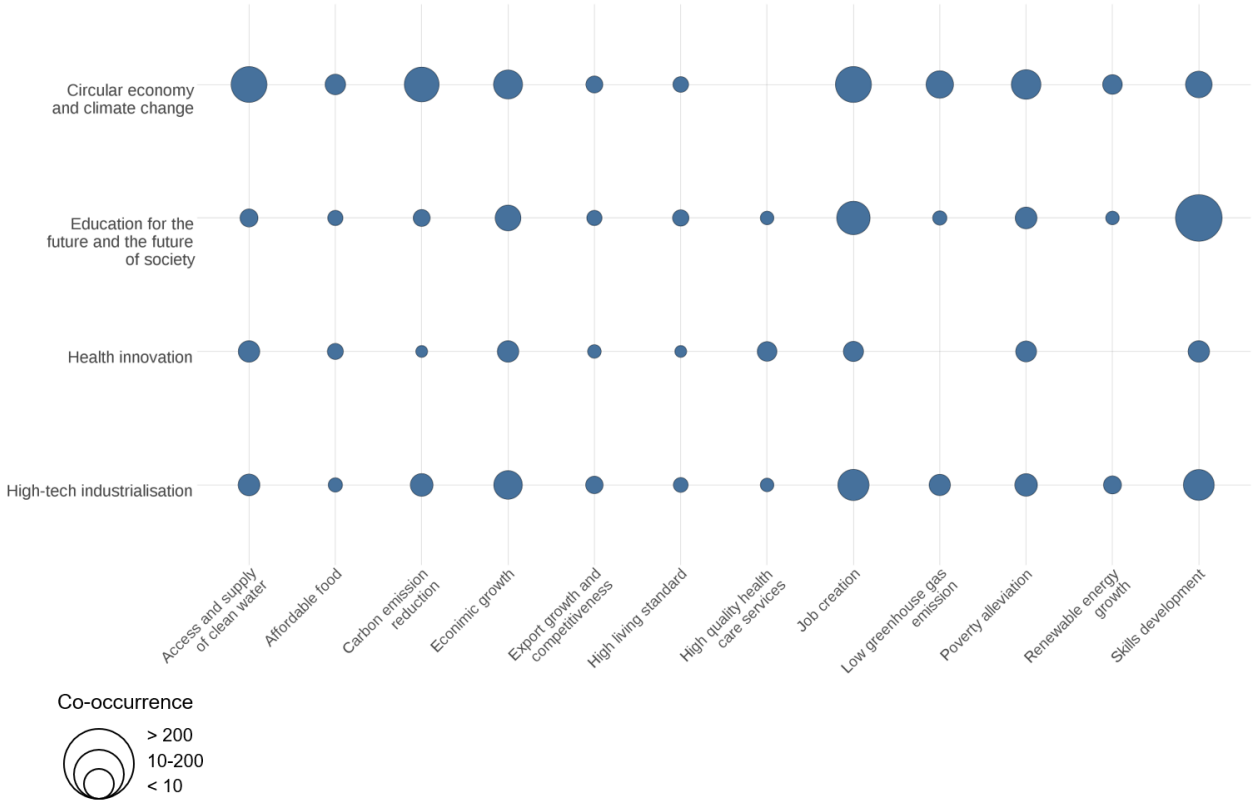

Figure 2.2. Matrix: 4 priorities and 12 indicators (in documents that mention South Africa)

Sections below will analyse those four main areas one by one.

2.1 Health innovation

Figure 2.3 presents the semantic analysis and key clusters emerged as a result it in the health innovation area.

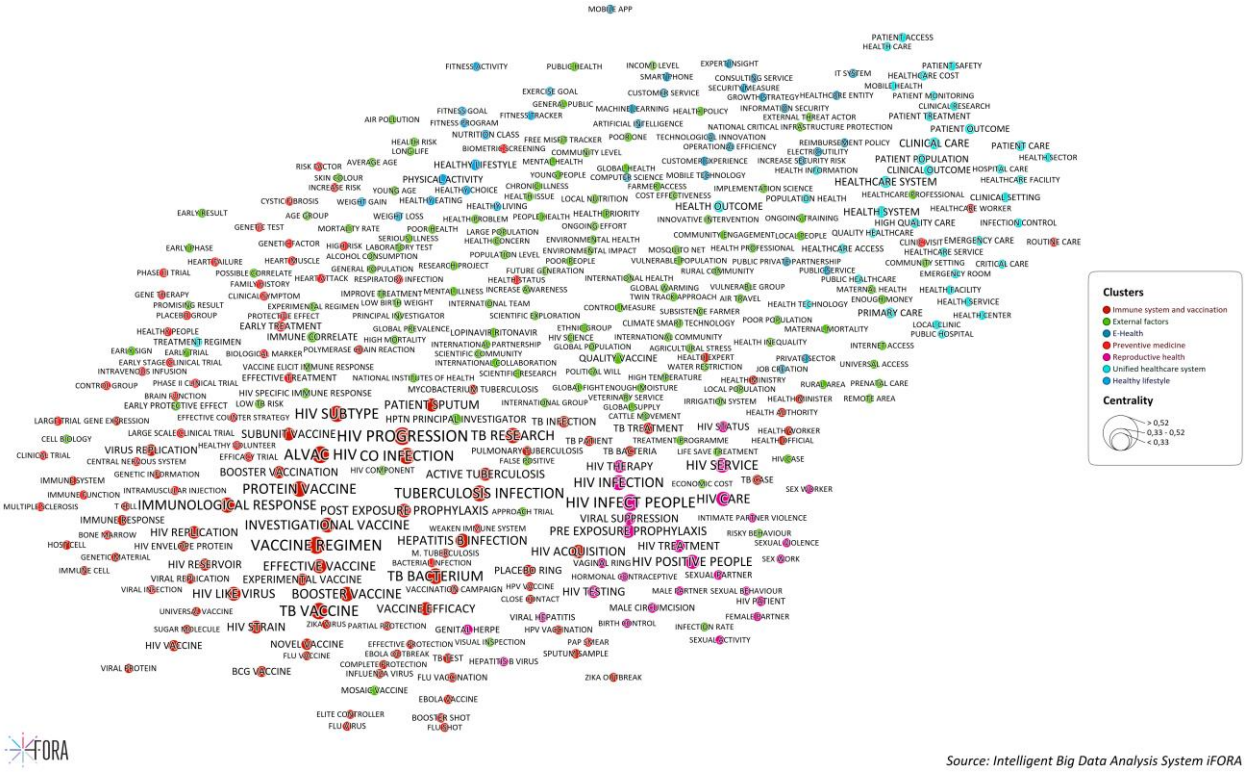

Figure 2.3. Semantic map

Semantic map shows the key issues in relation to health innovation in South Africa. Infectious diseases like HIV and Tuberculosis are the main health issues to be tackled in South Africa. In parallel, coinfection, which is the simultaneous infection of a host by multiple pathogen species appear to be one of the key health issues to be addressed. In relation to infections, vaccine development emerges as an important topic. South Africa appears to have a capacit to develop vaccines, which is an important capability for a country to prevent infectious diseases like HIV, Tuberculosis, and on-going SARS Covid-19.

The semantic analysis generated seven clusters as key themes under the health innovation topic. These are:

1. E-health
2. Preventive medicine
3. Unified healthcare system
4. Immune system and vaccination

5. Reproductive health
6. Healthy lifestyle
7. External factors, which have affect on health innovation

Figure 2.4 shows the trend map for health innovation.

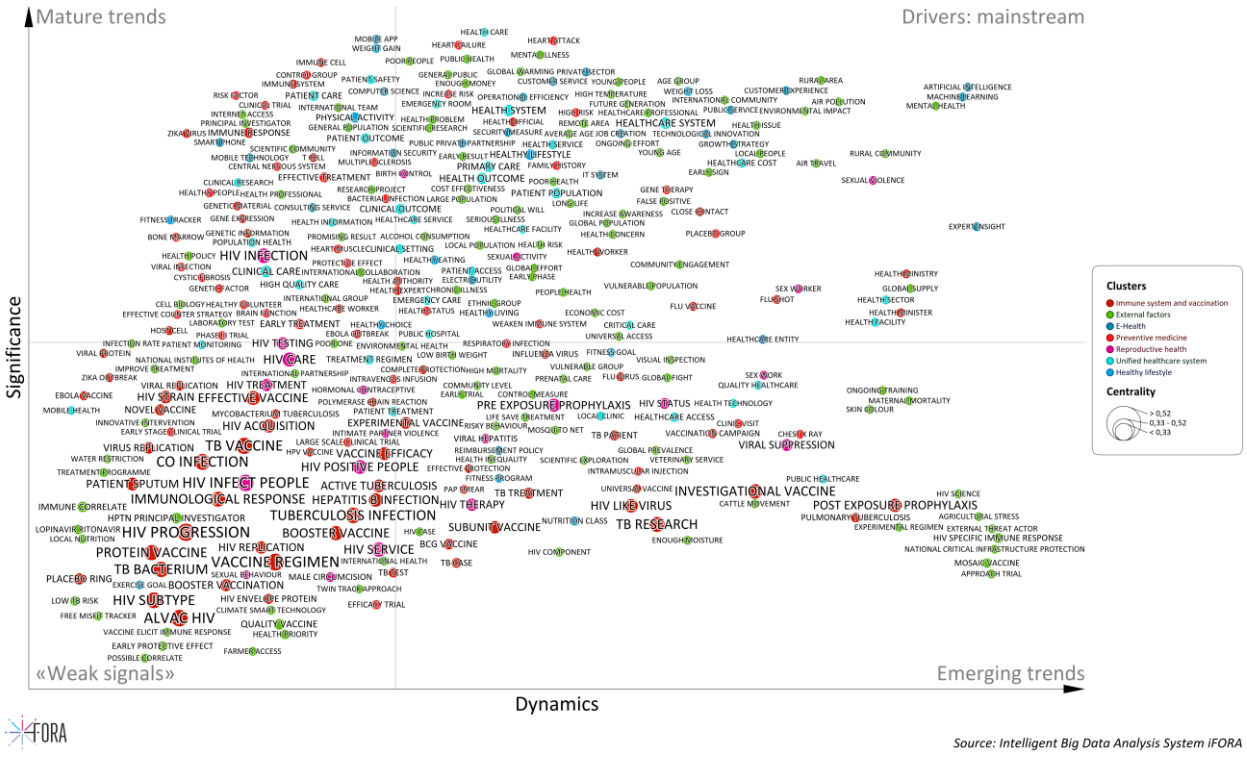

Figure 2.4. Trend map

According to the trendmap the mainstream trends are:

- HEALTHCARE SYSTEM.
- HEALTH SYSTEM.
- HEALTH OUTCOME.

Among these, the digitalization of the health industry emerges as the most significant and highly dynamic topic with is represented with the topics like Artificial Intelligence and Machine Learning.

Topics with the greatest centrality among mature trends are:

- HIV INFECTION
- CLINICAL CARE

- EARLY TREATMENT

Being mature, these trends have been present in South Africa for a while, and they will remain relevant in the country in a foreseenable future.

Topics with the greatest centrality among emerging trends are:

- TB RESEARCH
- INVESTIGATIONAL VACCINE
- HIV LIKE VIRUS

Particularly vaccine development for infectious diseases is becoming critical. This trend may be further supported by the on-going COVID-19 pandemic.

Topics with the greatest centrality among "weak signals" are:

- HIV PROGRESSION
- VACCINE REGIMEN
- ALVAC HIV

The topics are evenly spaced in all four quadrants. The most central topics are located at the bottom of the trend map, which indicates that the area "Health innovation" is currently at a stage of development and has not yet reached maturity and stability.

Figure 2.5 shows the relationships between the key clusters under health innovation in relation to the priorities (indicators) globally. Figure 2.6 then presents these relationships with the case of South Africa.

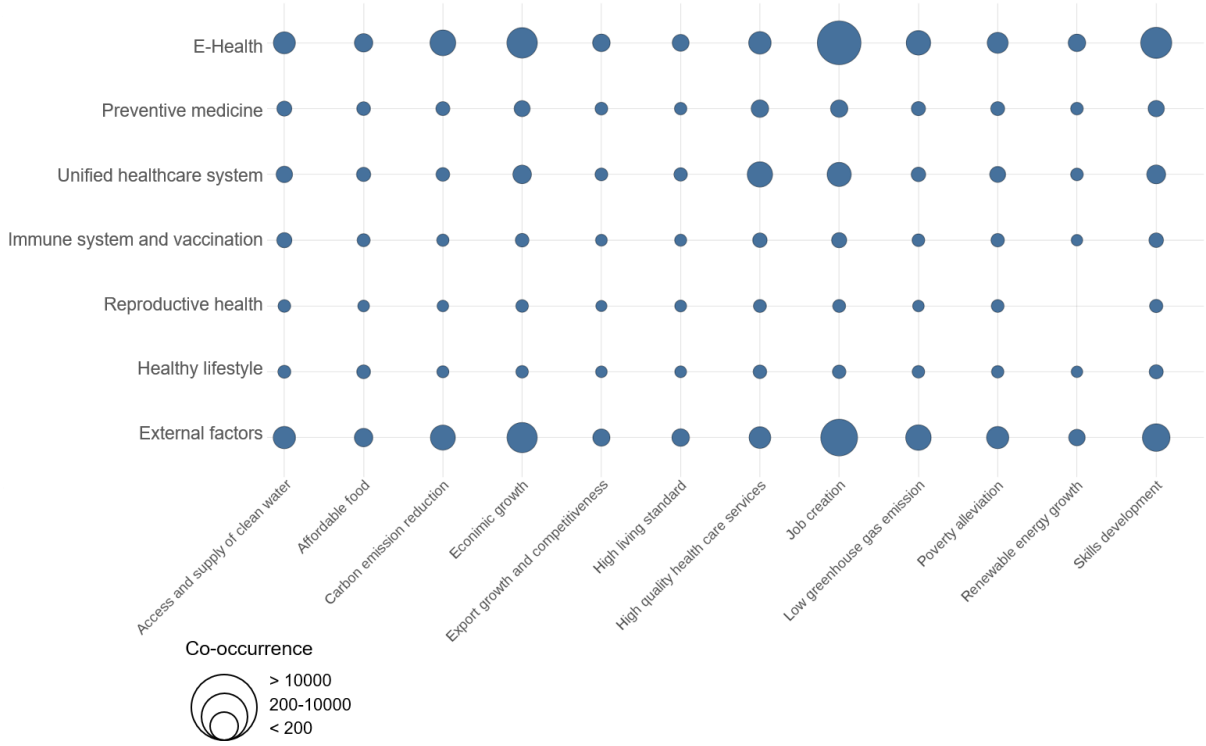

Figure 2.5. Clusters matrix: 7 clusters and 12 indicators (in all documents)

The matrix, built on the analysis of all documents around the world, shows that the most connected clusters and indicators are:

- Job creation and skills development are crucial for e-health
- The relationship between e-health and economic growth
- The necessity of high quality healthcare services for a unified healthcare system

Clusters with the greatest connection with most indicators are E-Health and External factors. The most important indicators are Skills development, Job creation, Economic growth, and High-quality health care services.

The matrix, built on the analysis of documents that mention South Africa (Figure 2.6), shows that the most connected clusters and indicators are the same as in all documents around the world:

- Jobs and skills need to be developed for e-health
- E-health is linked to economic growth
- Creation of a unified healthcare system in the country requires skills development and job creation

– Unified healthcare system is linked to economic growth, access and supply of clean water, and high quality healthcare services

Figure 2.6. Clusters matrix: 7 clusters and 12 indicators (in documents that mention South Africa)

Clusters with the greatest connection with most indicators are E-Health and External factors. The most important indicators are Skills development, Job creation, Economic growth. The indicator "High quality health care services" is less relevant to South Africa than Poverty alleviation that shows big importance. Access and supply to clean water is also significant and more relevant according to the analysis of documents that mention South Africa compared to all documents.

Figures 2.7 to 2.13 show the cluster maps under health innovation.

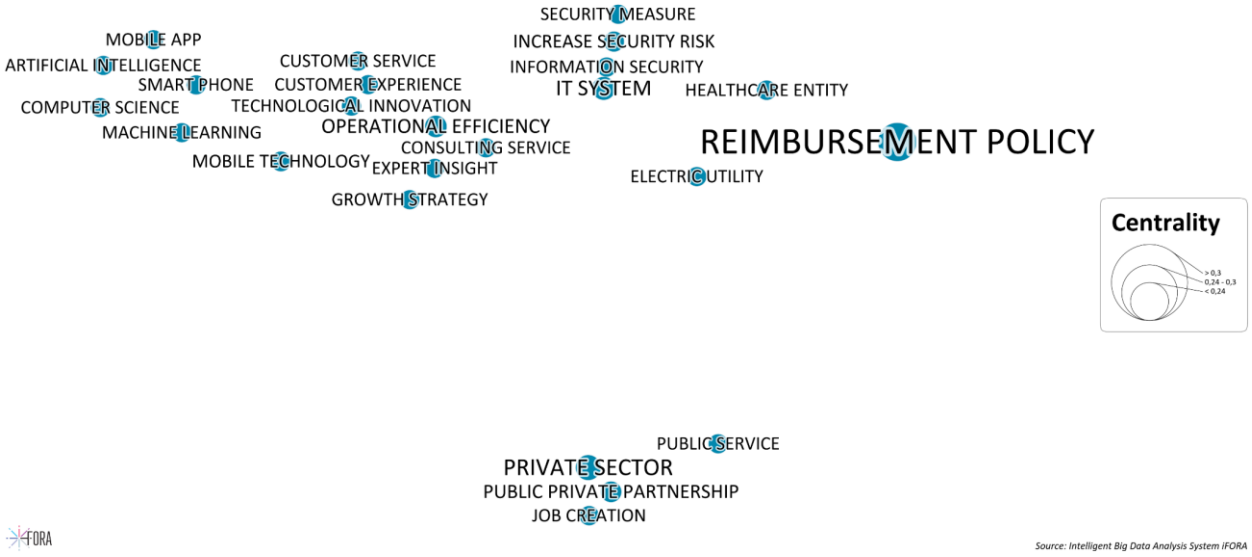

Figure 2.7. Cluster map. E-Health

The cluster map shows that topics with the greatest centrality on E-Health are:

- REIMBURSEMENT POLICY
- PRIVATE SECTOR
- IT SYSTEM
- OPERATIONAL EFFICIENCY
- PUBLIC PRIVATE PARTNERSHIP
- INCREASE SECURITY RISK
- MOBILE TECHNOLOGY
- HEALTHCARE ENTITY
- JOB CREATION
- TECHNOLOGICAL INNOVATION

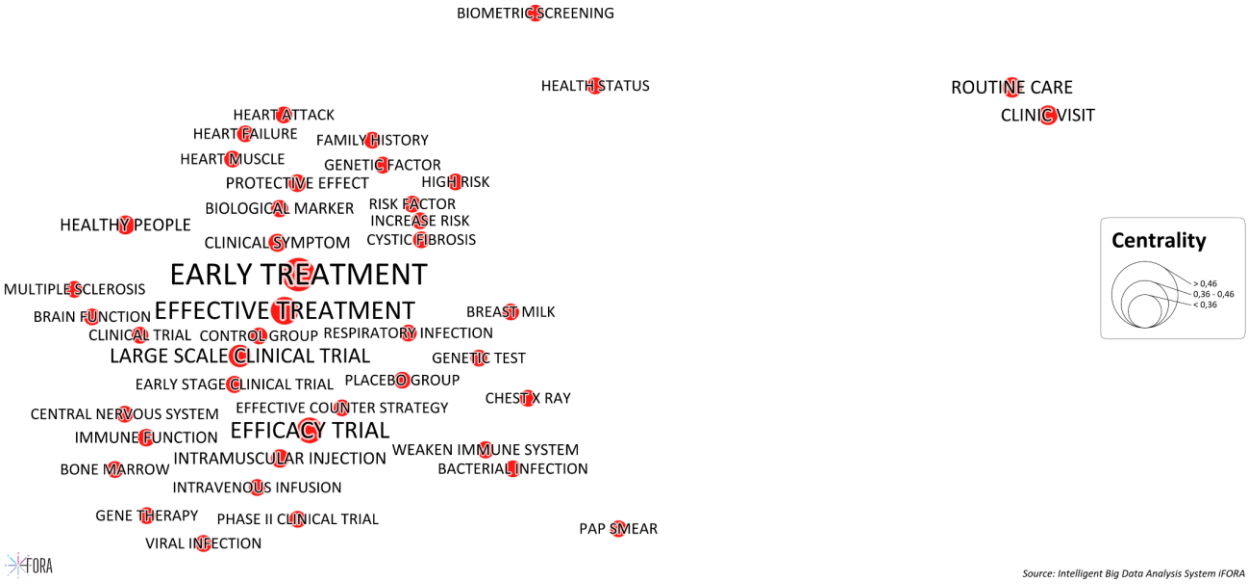

Figure 2.8. Cluster map. Preventive medicine

The cluster map shows that topics with the greatest centrality on Preventive medicine are:

- EARLY TREATMENT
- EFFECTIVE TREATMENT
- EFFICACY TRIAL
- LARGE SCALE CLINICAL TRIAL
- LARGE TRIAL
- ROUTINE CARE
- CLINIC VISIT
- HEALTHY PEOPLE
- INTRAMUSCULAR INJECTION
- CLINICAL SYMPTOM

Figure 2.9. Cluster map. Unified healthcare system

The cluster map shows that topics with the greatest centrality on Unified healthcare system are:

- CLINICAL CARE
- HEALTHCARE SYSTEM
- HEALTH SYSTEM
- HEALTH OUTCOME
- PRIMARY CARE
- PATIENT POPULATION
- CLINICAL OUTCOME
- PATIENT CARE
- PATIENT OUTCOME
- HIGH QUALITY CARE

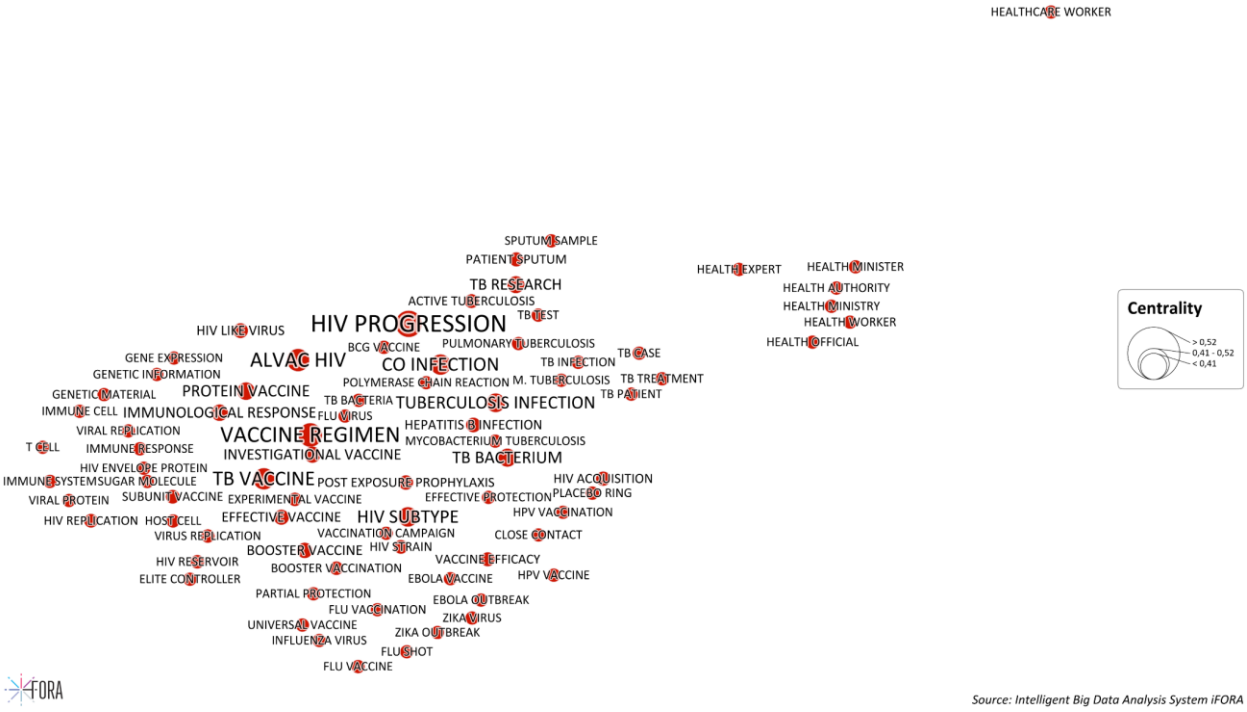

Figure 2.10. Cluster map. Immune system and vaccination

The cluster map shows that topics with the greatest centrality on Immune system and vaccination are:

- HIV PROGRESSION
- VACCINE REGIMEN
- ALVAC HIV
- TB VACCINE
- CO INFECTION
- HIV SUBTYPE
- TUBERCULOSIS INFECTION
- TB BACTERIUM
- PROTEIN VACCINE
- TB RESEARCH

The cluster "Immune system and vaccination" is one of the largest clusters of Health innovation. That indicates the thematic diversification of the cluster and shows a lot of inconsistent discussions of immune system and vaccination in the analyzed documents.

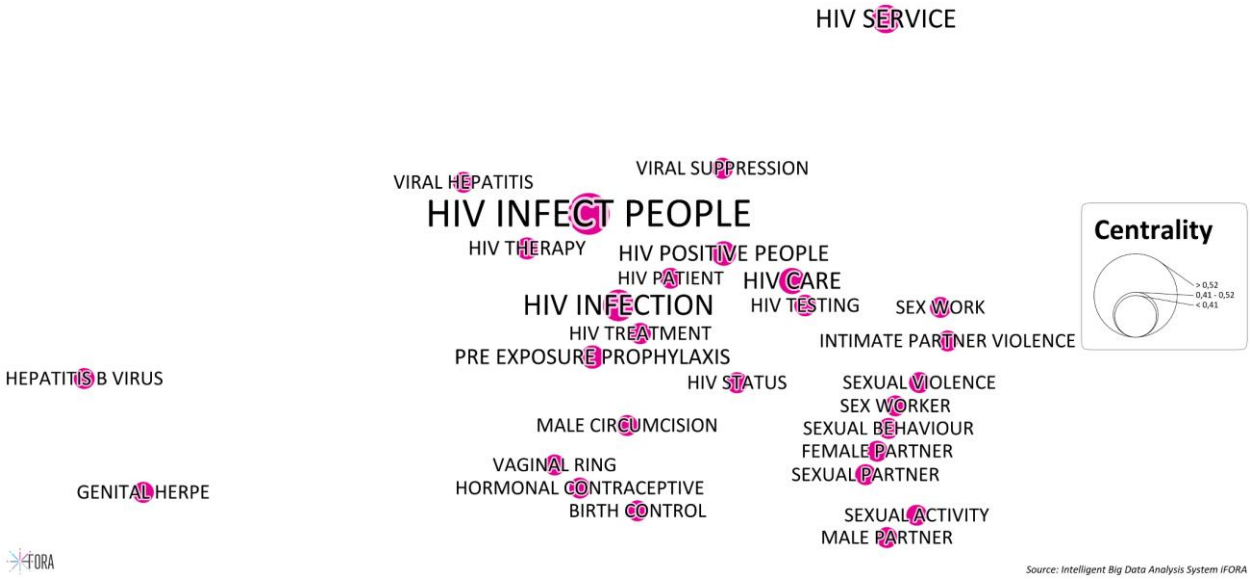

Figure 2.11. Cluster map. Reproductive health

The cluster map shows that topics with the greatest centrality on Reproductive health are:

- HIV INFECT PEOPLE
- HIV INFECTION
- HIV SERVICE
- HIV CARE
- HIV POSITIVE PEOPLE
- PRE-EXPOSURE PROPHYLAXIS
- HIV THERAPY
- HIV TESTING
- HIV TREATMENT
- VIRAL SUPPRESSION

Figure 2.12. Cluster map. Healthy lifestyle

The cluster map shows that topics with the greatest centrality on Healthy lifestyle are:

- HEALTHY LIFESTYLE
- PHYSICAL ACTIVITY
- NUTRITION CLASS
- HEALTHY LIVING
- HEALTHY EATING
- HEALTHY CHOICE
- WEIGHT LOSS
- EXERCISE GOAL
- WEIGHT GAIN
- FITNESS PROGRAM

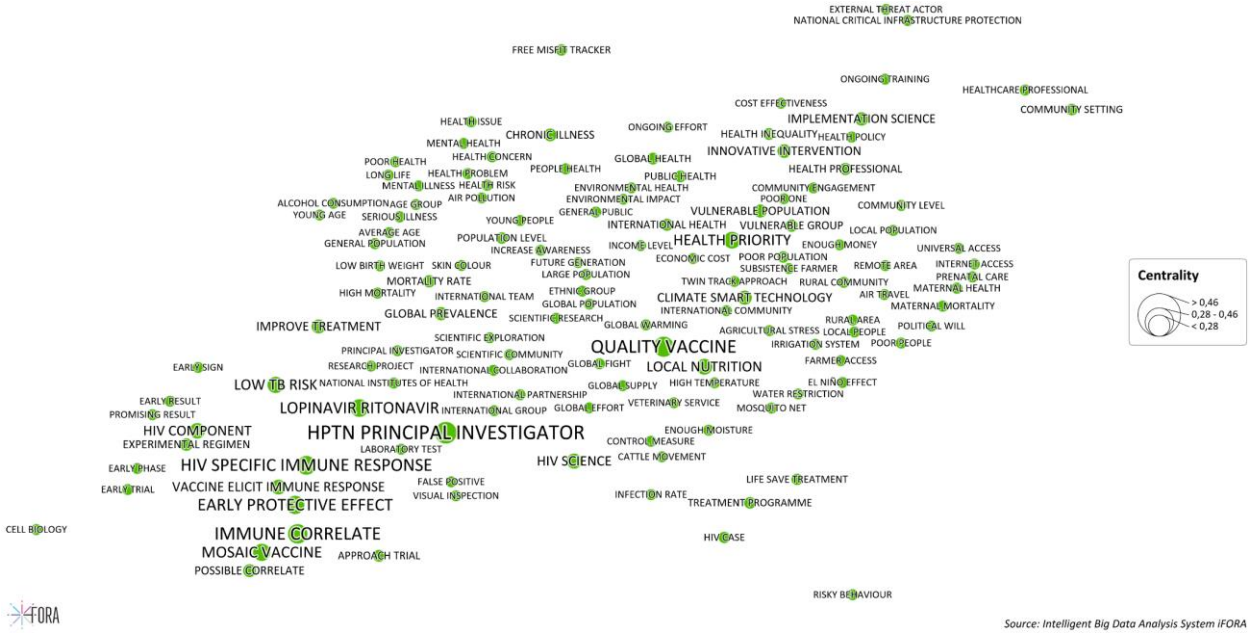

Figure 2.13. Cluster map. External factors

The cluster map shows that topics with the greatest centrality on External factors are:

- HPTN PRINCIPAL INVESTIGATOR
- QUALITY VACCINE
- IMMUNE CORRELATE
- HIV SPECIFIC IMMUNE RESPONSE
- EARLY PROTECTIVE EFFECT
- LOPINAVIR RITONAVIR
- MOSAIC VACCINE
- HEALTH PRIORITY
- LOW TB RISK
- LOCAL NUTRITION

The cluster "External factors" is one of the largest clusters of Health innovation. That indicates the thematic diversification of the cluster and means a lot of external factors that impact health innovation.

2.2 Circular economy/climate change

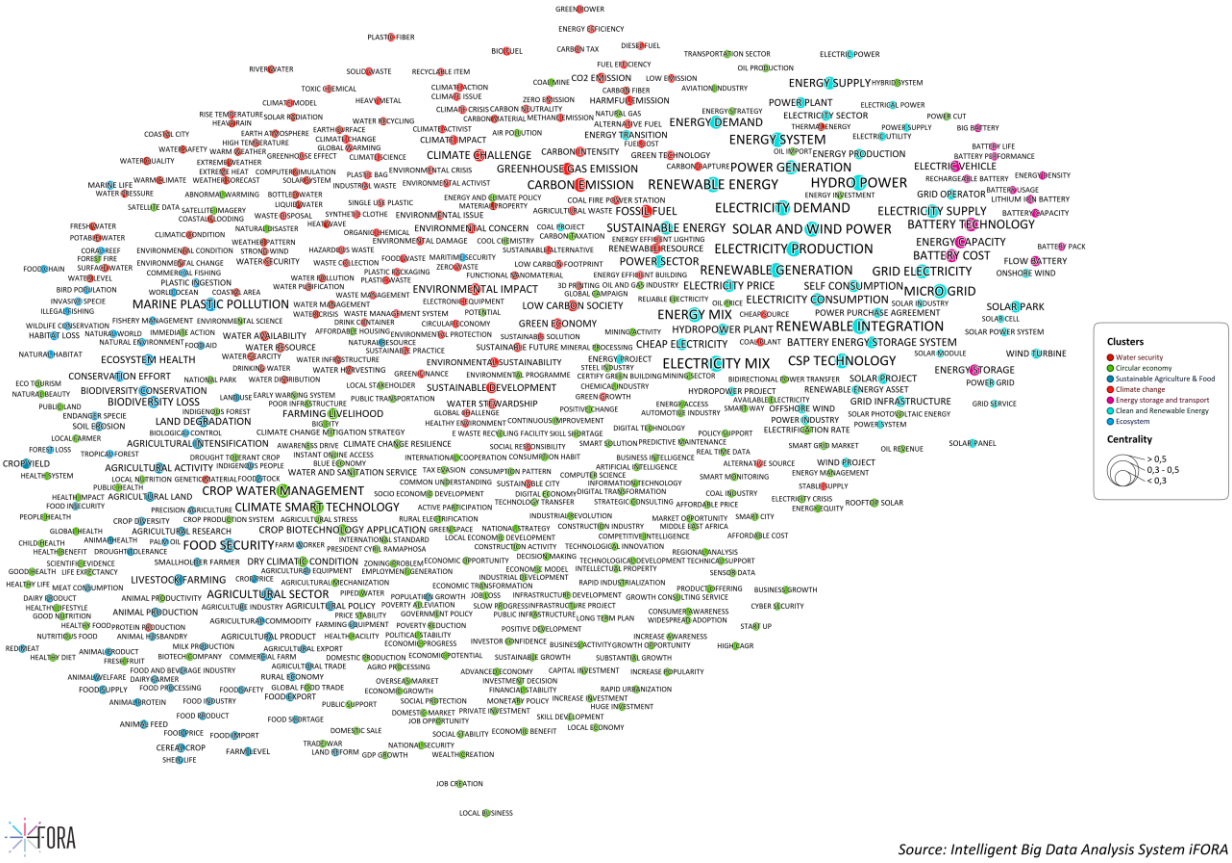

Figure 2.14. Semantic map

The semantic map shows that topics with the greatest centrality on the topics of circular economy and climate change are:

- ELECTRICITY MIX
- HYDRO POWER
- RENEWABLE INTEGRATION
- RENEWABLE ENERGY
- ELECTRICITY DEMAND
- SOLAR AND WIND POWER
- ELECTRICITY PRODUCTION
- CSP TECHNOLOGY
- ENERGY MIX
- ENERGY SYSTEM

Most central terms are relevant to electricity, energy and in particular to renewable energy. The points on the map are combined into one group, which shows thematic consistency of Circular economy/climate change and a high level of interconnection of the key topics of the area with each other.

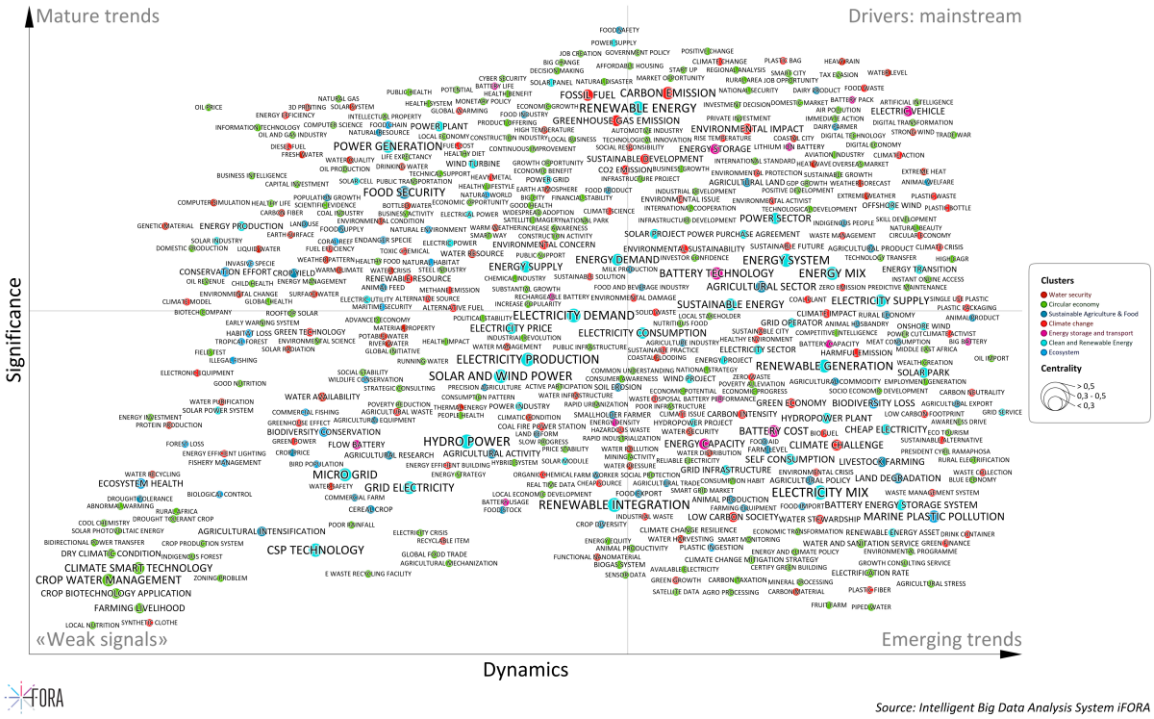

Figure 2.15. Trend map

The trend map shows that topics with the greatest centrality among drivers (mainstream) are:

- RENEWABLE ENERGY
- ENERGY MIX
- ENERGY SYSTEM

Topics with the greatest centrality among mature trends are:

- FOOD SECURITY
- POWER GENERATION
- ENERGY DEMAND

Topics with the greatest centrality among emerging trends are:

- ELECTRICITY MIX

- RENEWABLE GENERATION
- MARINE PLASTIC POLLUTION

Topics with the greatest centrality among "weak signals" are:

- HYDRO POWER
- RENEWABLE INTEGRATION
- ELECTRICITY DEMAND

The topics are evenly spaced in all four quadrants. The central topics are also located in all four quadrants, which indicates a balanced and equable development of Circular economy/climate change area.

The semantic analysis generated seven clusters as key topics under Circular economy/climate change:

1. Climate change
2. Energy storage and transport
3. Ecosystem
4. Water security
5. Sustainable agriculture and food
6. Circular economy
7. Clean and renewable energy

The results of the analysis showed that climate change and circular economy can be considered as two interlinked but separate topics.

Figure 2.16 and 2.17 shows the matrices with the clusters and their impacts on the key indicators/priorities. The first figure shows the global picture and the second one is specific to South Africa.

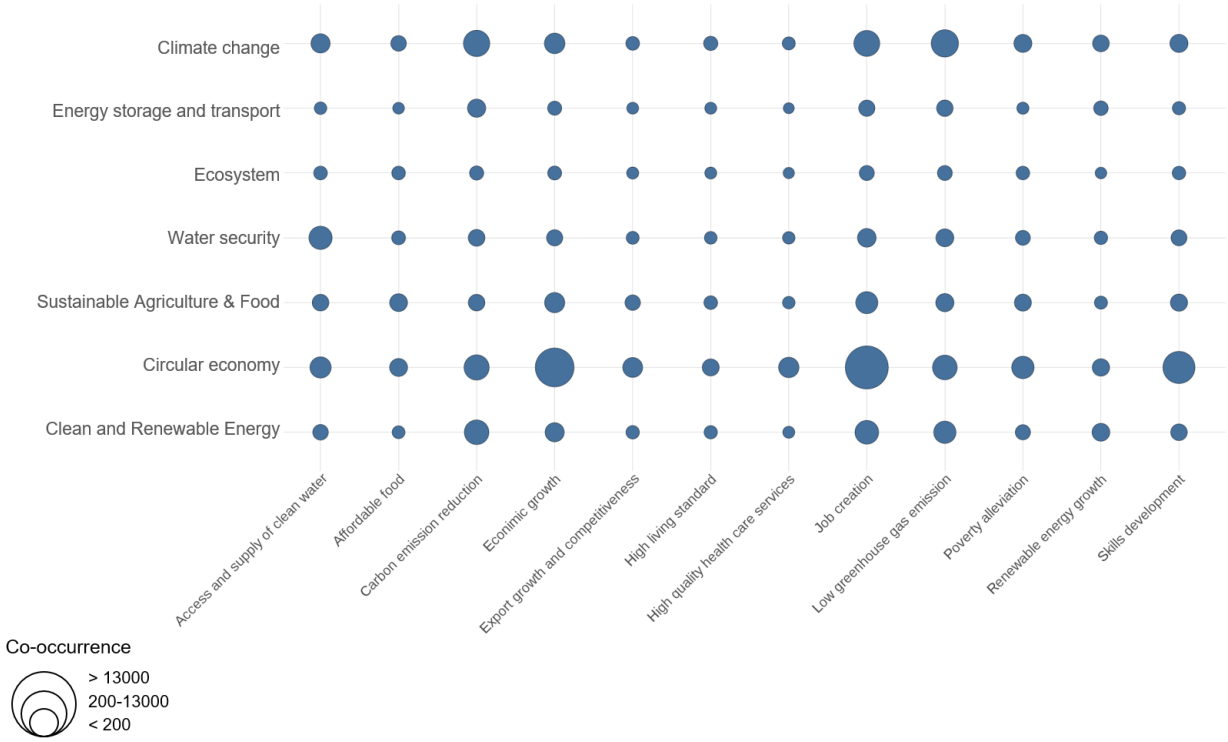

Figure 2.16. Clusters matrix: 7 clusters and 12 indicators (in all documents)

The matrix, built on the analysis of all documents around the world, shows that the most connected clusters and indicators are:

- Circular economy and Job creation
- Circular economy and Economic growth
- Circular economy and Skills development
- Climate change and Low greenhouse gas emission

Clusters with the greatest connection with most indicators are Circular economy, Climate change, and Clean and Renewable Energy. The most important indicators are Job creation, Economic growth, Low greenhouse gas emission, Skills development, Carbon emission reduction.

The matrix, built on the analysis of documents that mention South Africa, shows that the most connected clusters and indicators are:

- Circular economy, job creation and skills development: New skills need to be developed and jobs need to be created following the requirements of the circular economy

- Circular economy and Economic growth: Circular economy appears to be the new driver of the economic growth for SouthAfrica. It is also expected to contribute to poverty alleviation
- Climate change is very much dependent on the low greenhouse gas emission and carbon emission reduction. Economic growth based on circular economy will have a positive impact for controlling climate change. Therefore, climate change is very much dependent on economic growth, skills development and jobcreation
- Clean and renewable energy is required for carbon emission reduction. Economic growth should be based on the use of clean and renewable energy

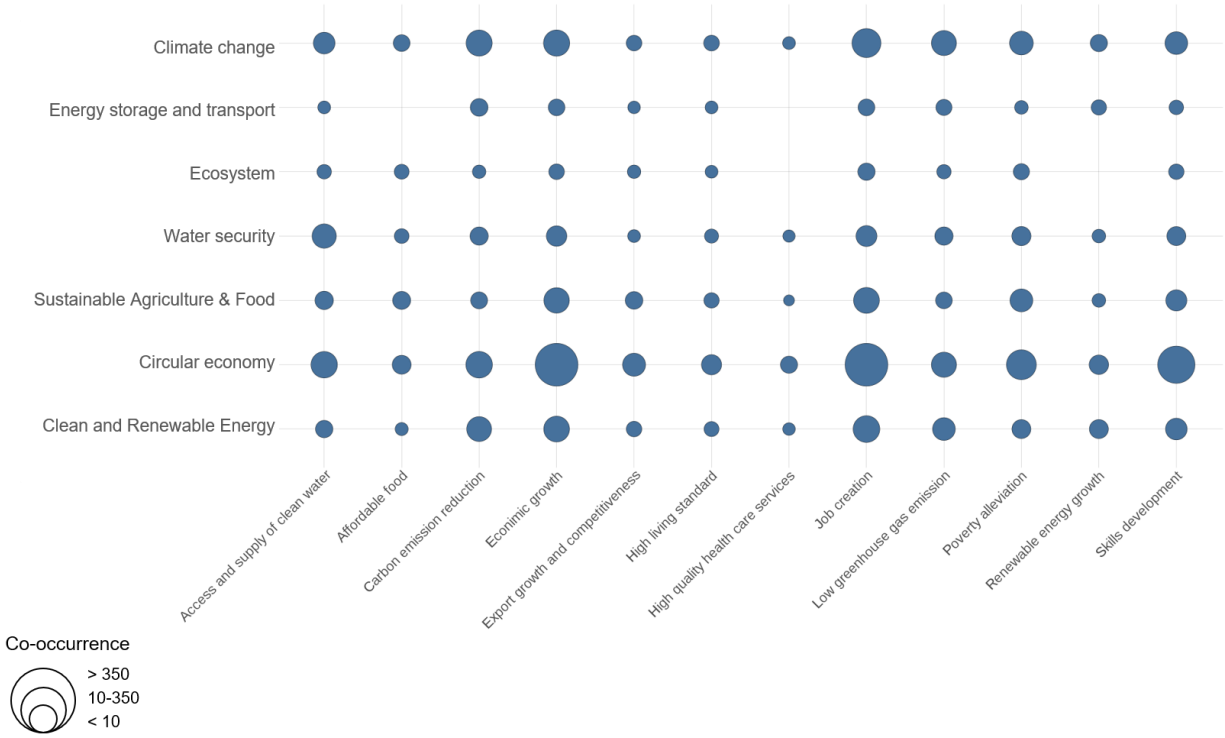

Figure 2.17. Clusters matrix: 7 clusters and 12 indicators (in documents that mention South Africa)

Clusters with the greatest connection with most indicators are Circular economy, Climate change, and Clean and Renewable Energy. The most important indicators are Job creation, Economic growth, Low greenhouse gas emission, Poverty alleviation, and Skills development.

Access and supply of clean water and Poverty alleviation appeared to be more significant indicators according to the analysis of documents that mention South Africa compared to all documents.

Figures 2.18 to 2.24 shows the cluster maps for Circular economy/climate change.

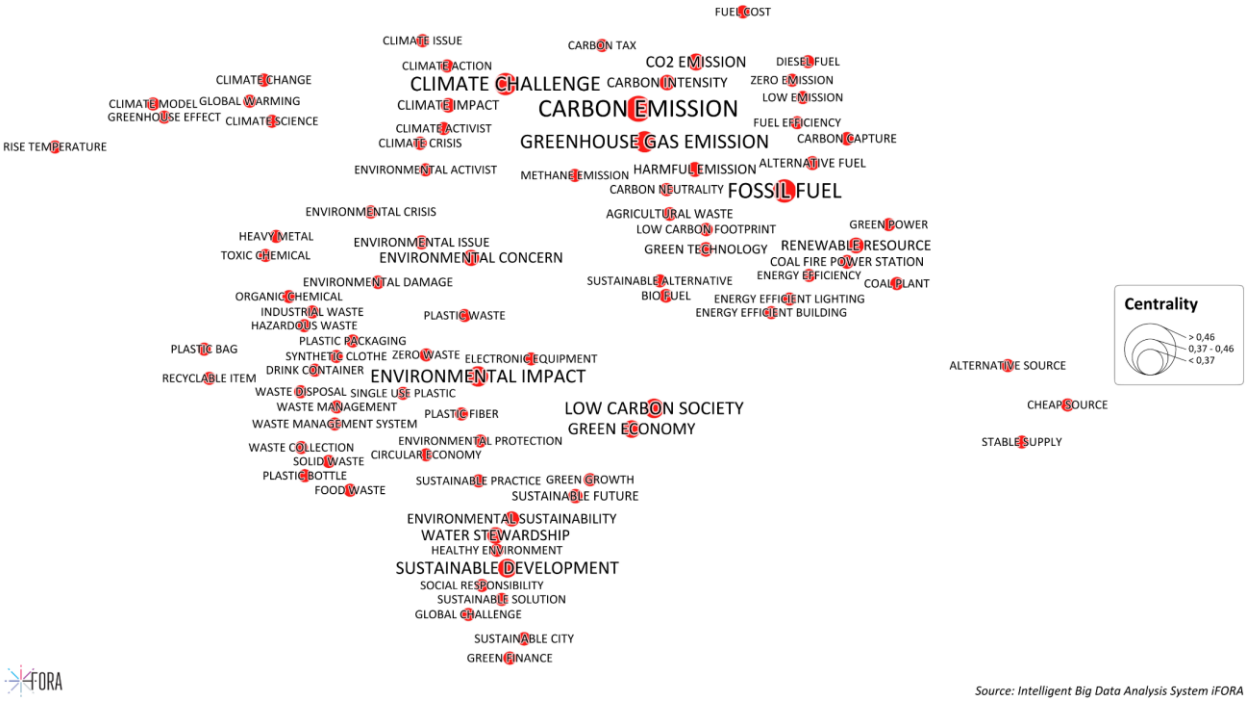

Figure 2.18. Cluster map. Climate change

The cluster map shows that topics with the greatest centrality on Climate change are:

- CARBON EMISSION
- FOSSIL FUEL
- CLIMATE CHALLENGE
- GREENHOUSE GAS EMISSION
- ENVIRONMENTAL IMPACT
- LOW CARBON SOCIETY
- SUSTAINABLE DEVELOPMENT
- GREEN ECONOMY
- CO2 EMISSION
- WATER STEWARDSHIP

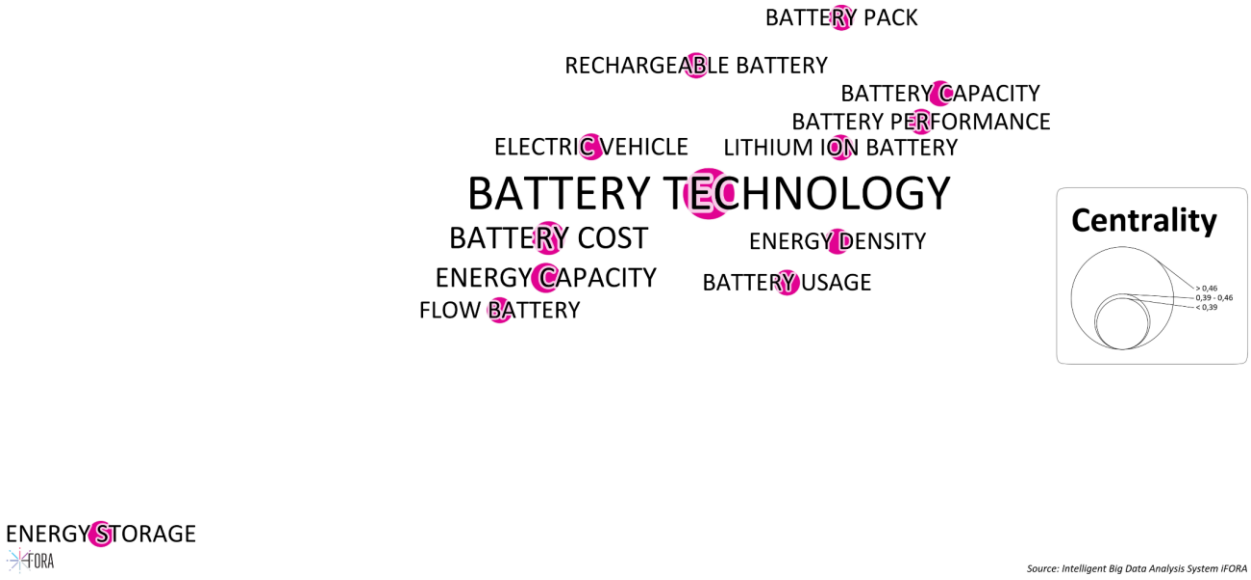

Figure 2.19. Cluster map. Energy storage and transport

The cluster map shows that topics with the greatest centrality on Energy storage and transport are:

- BATTERY TECHNOLOGY
- BATTERY COST
- ENERGY CAPACITY
- ELECTRIC VEHICLE
- ENERGY STORAGE
- FLOW BATTERY
- LITHIUM-ION BATTERY
- BATTERY CAPACITY
- RECHARGEABLE BATTERY
- BATTERY PACK

Figure 2.20. Cluster map. Ecosystem

The cluster map shows that topics with the greatest centrality on Ecosystem are:

- MARINE PLASTIC POLLUTION
- BIODIVERSITY LOSS
- ECOSYSTEM HEALTH
- CONSERVATION EFFORT
- BIODIVERSITY CONSERVATION
- PLASTIC INGESTION
- HABITAT LOSS
- MARINE LIFE
- ENDANGER SPECIE
- NATURAL HABITAT

Figure 2.21. Cluster map. Water security

The cluster map shows that topics with the greatest centrality on Water security are:

- WATER AVAILABILITY
- WATER RESOURCE
- WATER SECURITY
- WATER HARVESTING
- WATER SCARCITY
- WATER MANAGEMENT
- WATER QUALITY
- WATER POLLUTION
- WATER RECYCLING
- SURFACE WATER

Figure 2.22. Cluster map. Sustainable Agriculture & Food

The cluster map shows that topics with the greatest centrality on Sustainable Agriculture and Food are:

- FOOD SECURITY
- AGRICULTURAL SECTOR
- LAND DEGRADATION
- LIVESTOCK FARMING
- AGRICULTURAL ACTIVITY
- AGRICULTURAL INTENSIFICATION
- CROP YIELD
- AGRICULTURAL LAND
- AGRICULTURAL POLICY
- ANIMAL PRODUCTION

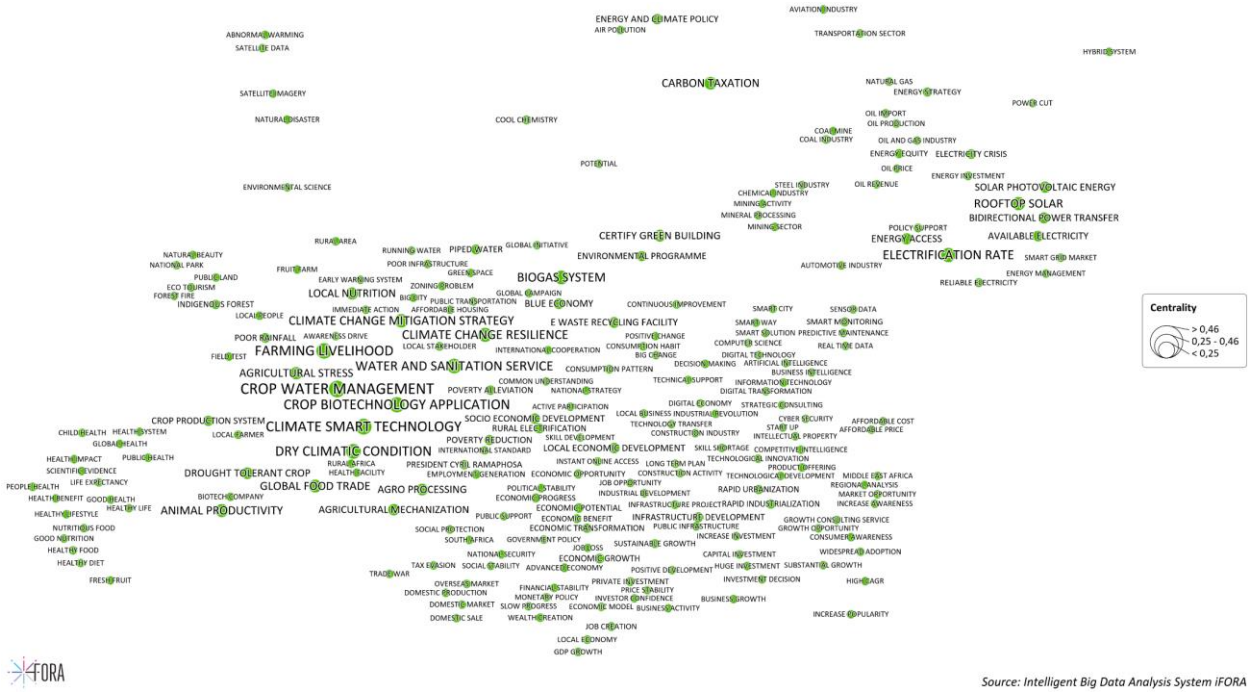

Figure 2.23. Cluster map. Circular economy

The cluster map shows that topics with the greatest centrality on Circular economy are:

- CROP WATER MANAGEMENT
- CLIMATE SMART TECHNOLOGY
- FARMING LIVELIHOOD
- CROP BIOTECHNOLOGY APPLICATION
- DRY CLIMATIC CONDITION
- WATER AND SANITATION SERVICE
- ELECTRIFICATION RATE
- CLIMATE CHANGE RESILIENCE
- BIOGAS SYSTEM
- CLIMATE CHANGE MITIGATION STRATEGY

The cluster "Circular economy" is one of the largest clusters of Circular economy/climate change. That indicates the importance and thematic diversification of the cluster and shows a lot of inconsistent discussions of circular economy in the analyzed documents.

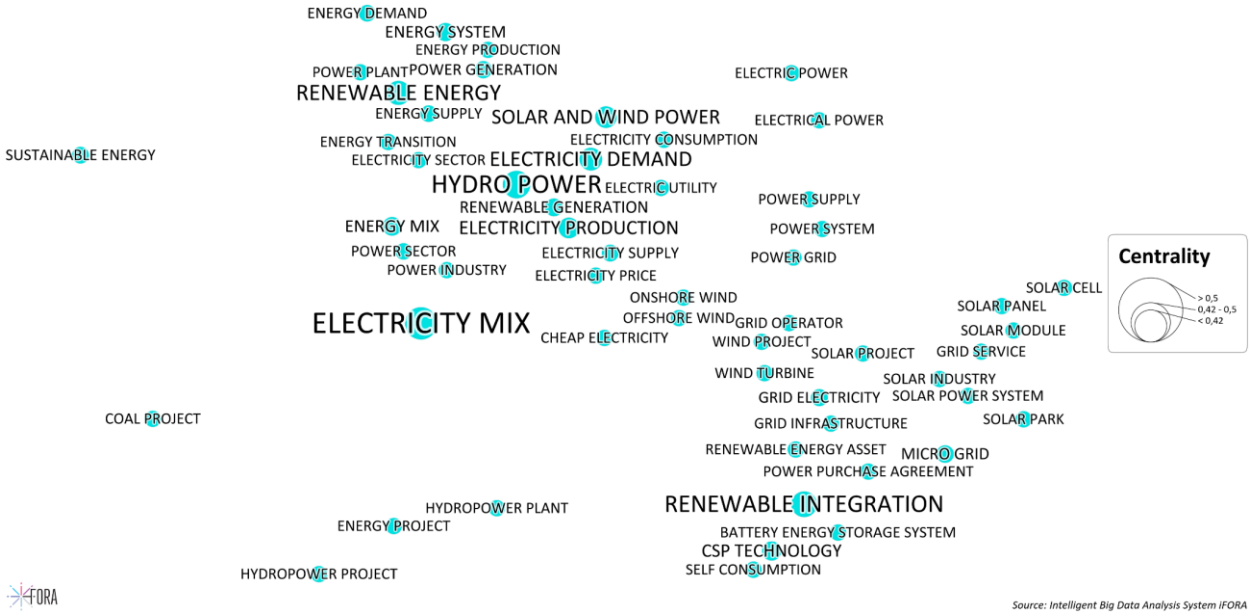

Figure 2.24. Cluster map. Clean and Renewable Energy

The cluster map shows that topics with the greatest centrality on Clean and Renewable Energy are:

- ELECTRICITY MIX
- HYDRO POWER
- RENEWABLE INTEGRATION
- RENEWABLE ENERGY
- ELECTRICITY DEMAND
- SOLAR AND WIND POWER
- ELECTRICITY PRODUCTION
- CSP TECHNOLOGY
- ENERGY MIX
- ENERGY SYSTEM

2.3 High-tech industrialisation

Figure 2.25 shows the cluster map for High-tech industrialisation.

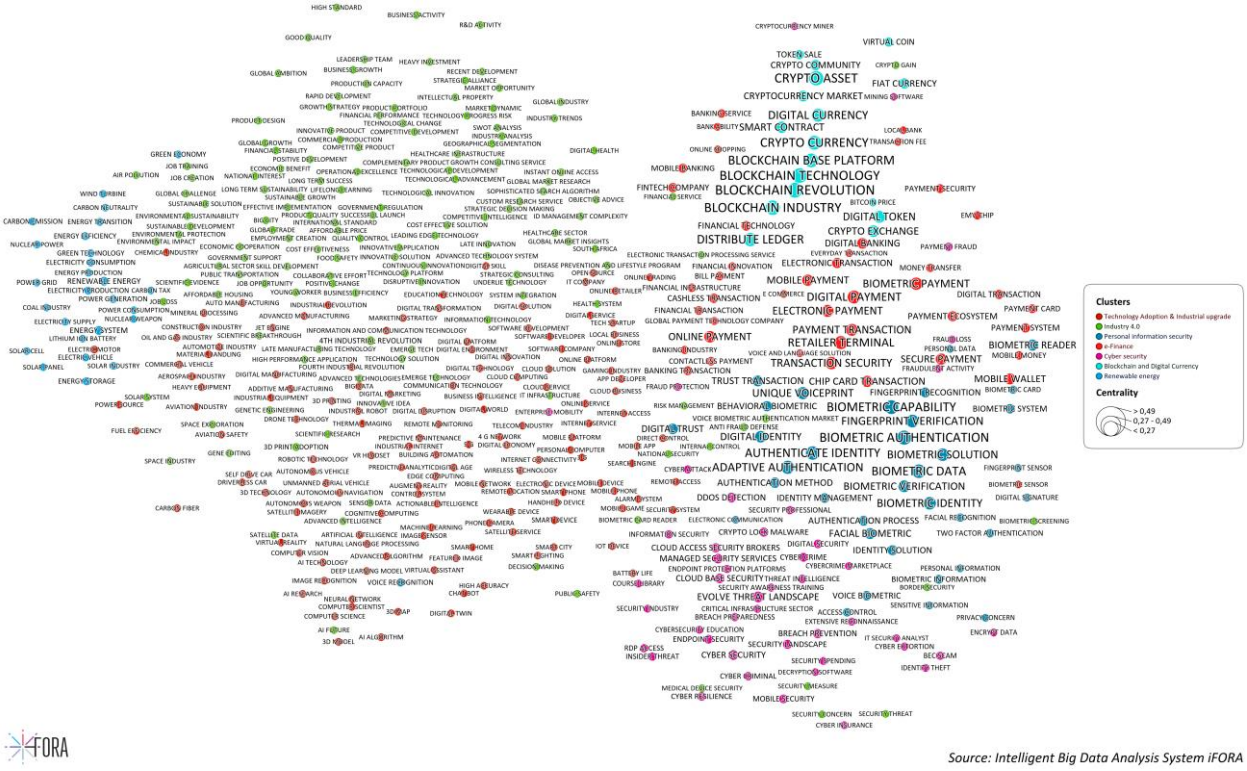

Figure 2.25. Semantic map

The semantic map shows that topics with the greatest centrality on Health innovation are:

- BLOCKCHAIN REVOLUTION
- BLOCKCHAIN TECHNOLOGY
- BLOCKCHAIN INDUSTRY
- CRYPTO ASSET
- BIOMETRIC AUTHENTICATION
- CRYPTO CURRENCY
- BIOMETRIC CAPABILITY
- BLOCKCHAIN BASE PLATFORM
- BIOMETRIC DATA
- AUTHENTICATE IDENTITY

The points on the map are combined into one group, which shows thematic consistency of High-tech industrialisation and a high level of interconnection of the key topics of the direction with each other.

Topics covered by High-tech industrialisation clustered around seven topics, including:

1. Blockchain and digital currency
2. Cybersecurity
3. Industry 4.0
4. Technology adoption and industrial upgrade
5. E-finance
6. Personal information security
7. Renewable energy

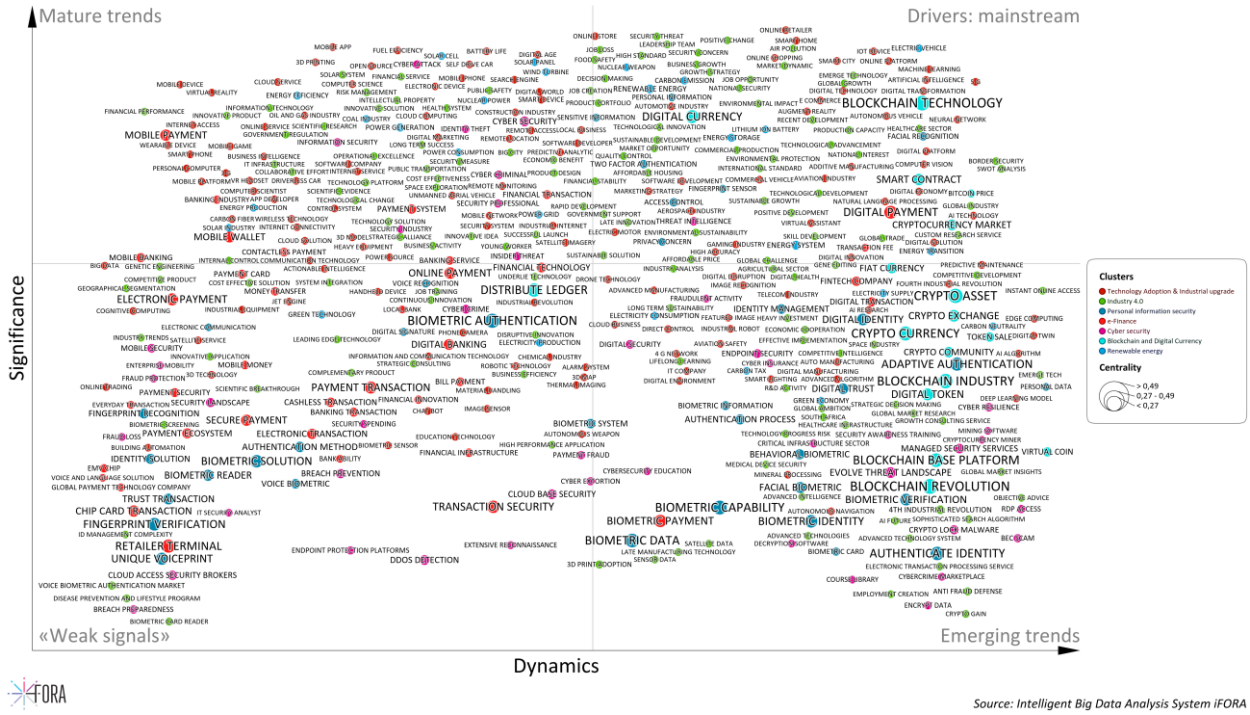

Figure 2.26. Trend map

The trend map shows that topics with the greatest centrality among drivers (mainstream) are:

- BLOCKCHAIN TECHNOLOGY
- DIGITAL CURRENCY
- DIGITAL PAYMENT

Topics with the greatest centrality among mature trends are:

- MOBILE PAYMENT
- MOBILE WALLET
- CYBER SECURITY

Topics with the greatest centrality among emerging trends are:

- BLOCKCHAIN REVOLUTION
- BLOCKCHAIN INDUSTRY
- CRYPTO ASSET

Topics with the greatest centrality among "weak signals" are:

- BIOMETRIC AUTHENTICATION
- DISTRIBUTE LEDGER
- RETAILER TERMINAL

The topics are evenly spaced in all four quadrants. The most central topics are located at the bottom of the trend map, which indicates that the area "High-tech industrialisation " is currently at a stage of development and has not yet reached maturity and stability.

Figures 2.27 and 2.28 present the matrices showing High-tech industry clusters in relation to the 12 indicators/priorities, first globally and then in specific to South Africa.

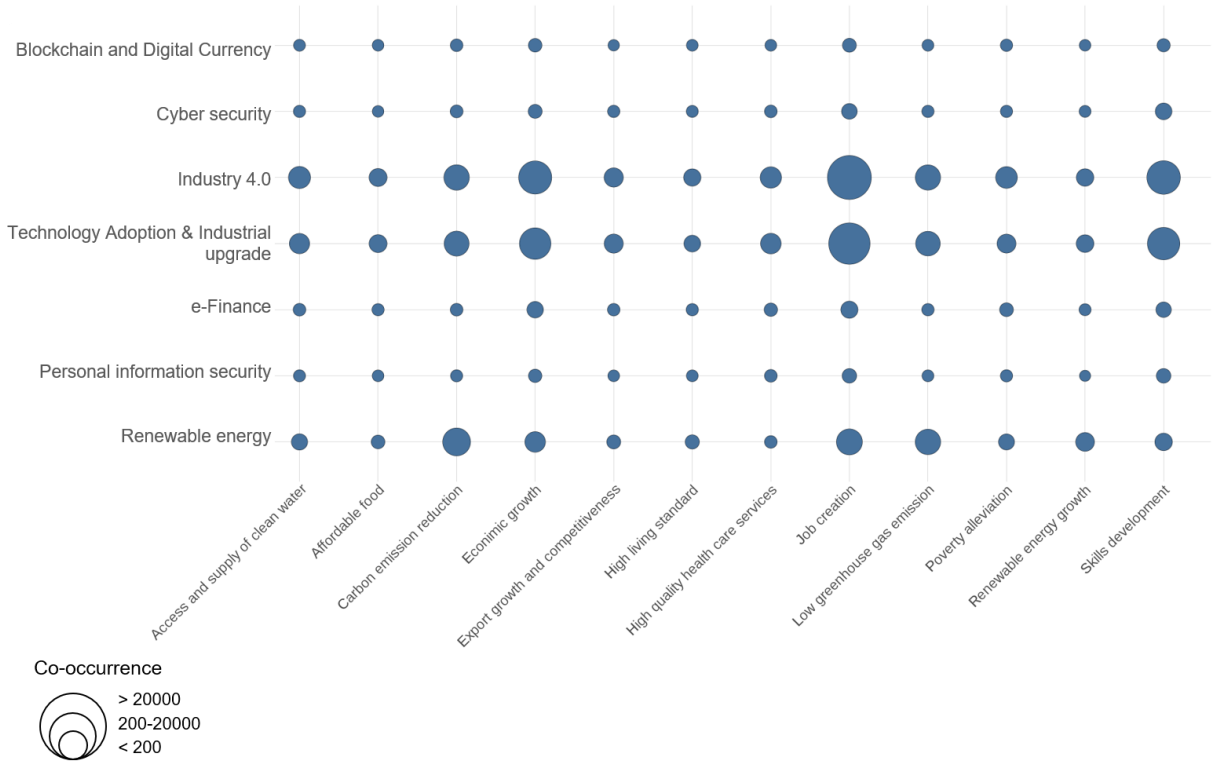

Figure 2.27. Clusters matrix: 7 clusters and 12 indicators (in all documents)

The matrix, built on the analysis of all documents around the world (Figure 2.27), shows that the most connected clusters and indicators are:

- Industry 4.0 and Job creation.
- Technology Adoption & Industrial upgrade and Job creation.
- Industry 4.0 and Skills development.
- Technology Adoption & Industrial upgrade and Skills development.
- Industry 4.0 and Economic growth.
- Technology Adoption & Industrial upgrade and Economic growth.
- Renewable energy and Carbon emission reduction.

Clusters with the greatest connection with most indicators are Industry 4.0 and Technology Adoption and Industrial upgrade. The most important indicators are Skills development, Job creation and Economic growth.

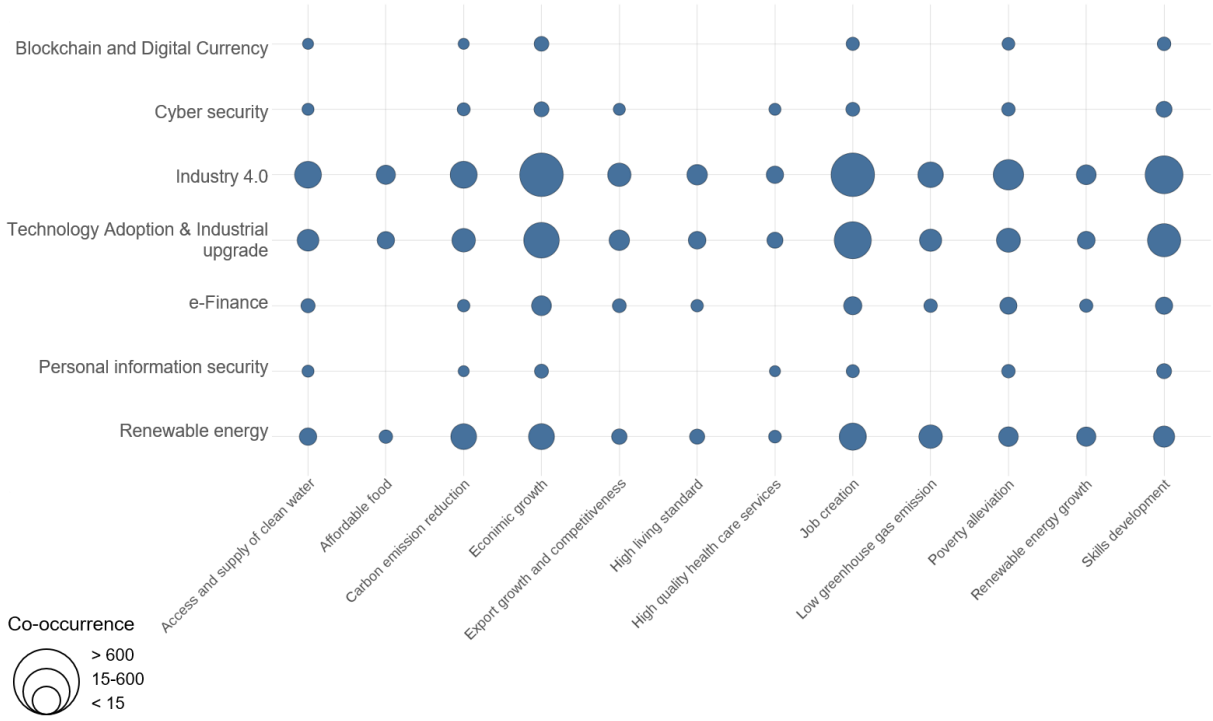

Figure 2.28. Clusters matrix: 7 clusters and 12 indicators (in documents that mention South Africa)

The matrix, built on the analysis of documents that mention South Africa (Figure 2.28), shows that the most connected clusters and indicators are:

- Industry 4.0 appears to be the new driver of the economic growth

– New skills need to be developed and jobs need to be created for implementing Industry 4.0 in the coming decade
– In order to achieve the transformation to Industry 4.0,and achieve the economic growth based on this concept, there is a need for technology adoption and industrial upgrade
– Transformations to Industry 4.0 and the Circular economy should go hand in hand and be based on clean, sustainable and renewable energy sources

Clusters with the greatest connection with most indicators are Industry 4.0 and Technology Adoption; Industrial upgrade. The most important indicators are Skills development, Job creation and Economic growth. "Economic growth" and " Skills development " indicators are more relevant to South Africa according to the analysis of documents that mention South Africa compared to all documents.

Figures 2.29 to 2.35 shows the detailed maps for the clusetrs of the High-tech industrialisation.

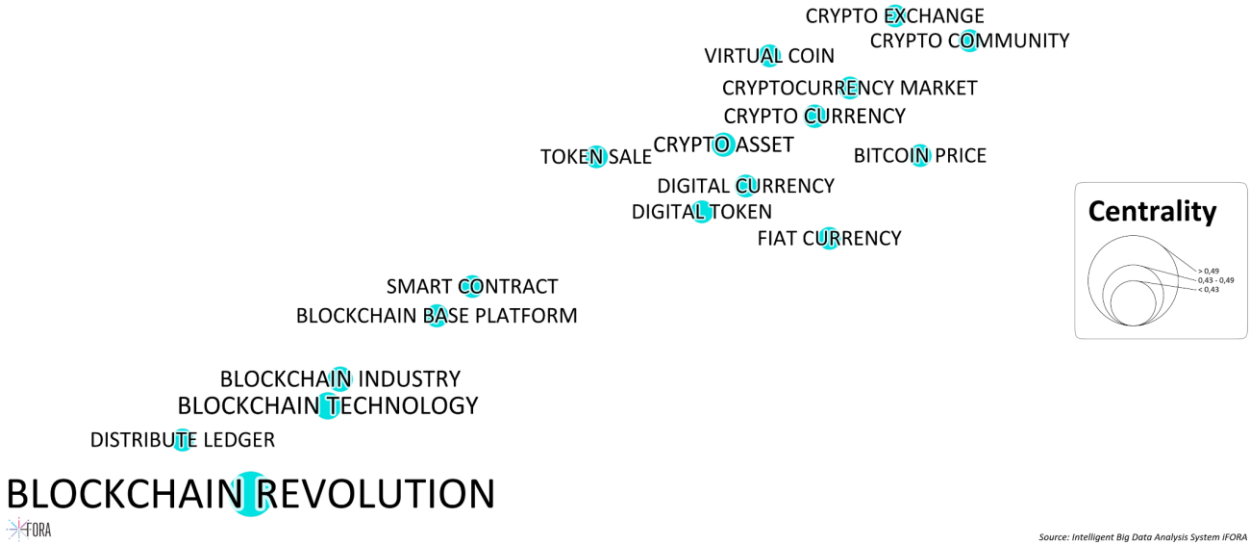

Figure 2.29. Cluster map. Blockchain and Digital Currency

The cluster map shows that topics with the greatest centrality on Blockchain and Digital Currency are:

– BLOCKCHAIN REVOLUTION
– BLOCKCHAIN TECHNOLOGY
– BLOCKCHAIN INDUSTRY

– CRYPTO ASSET
– CRYPTO CURRENCY
– BLOCKCHAIN BASE PLATFORM
– DISTRIBUTE LEDGER
– DIGITAL CURRENCY
– DIGITAL TOKEN
– CRYPTO EXCHANGE

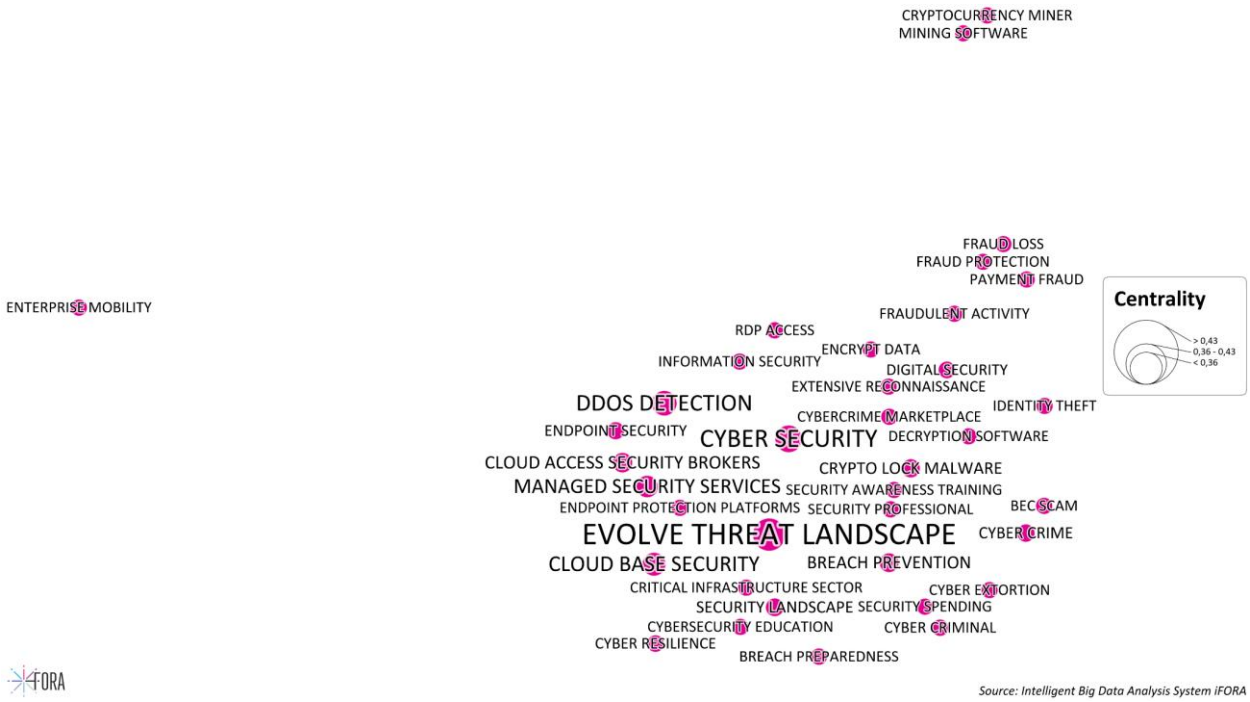

Figure 2.30. Cluster map. Cyber security

The cluster map shows that topics with the greatest centrality on Cyber security are:

– EVOLVE THREAT LANDSCAPE
– CYBER SECURITY
– DDOS DETECTION
– CLOUD BASE SECURITY
– MANAGED SECURITY SERVICES
– CLOUD ACCESS SECURITY BROKERS
– BREACH PREVENTION
– CRYPTO LOCK MALWARE
– SECURITY LANDSCAPE
– CYBER CRIME

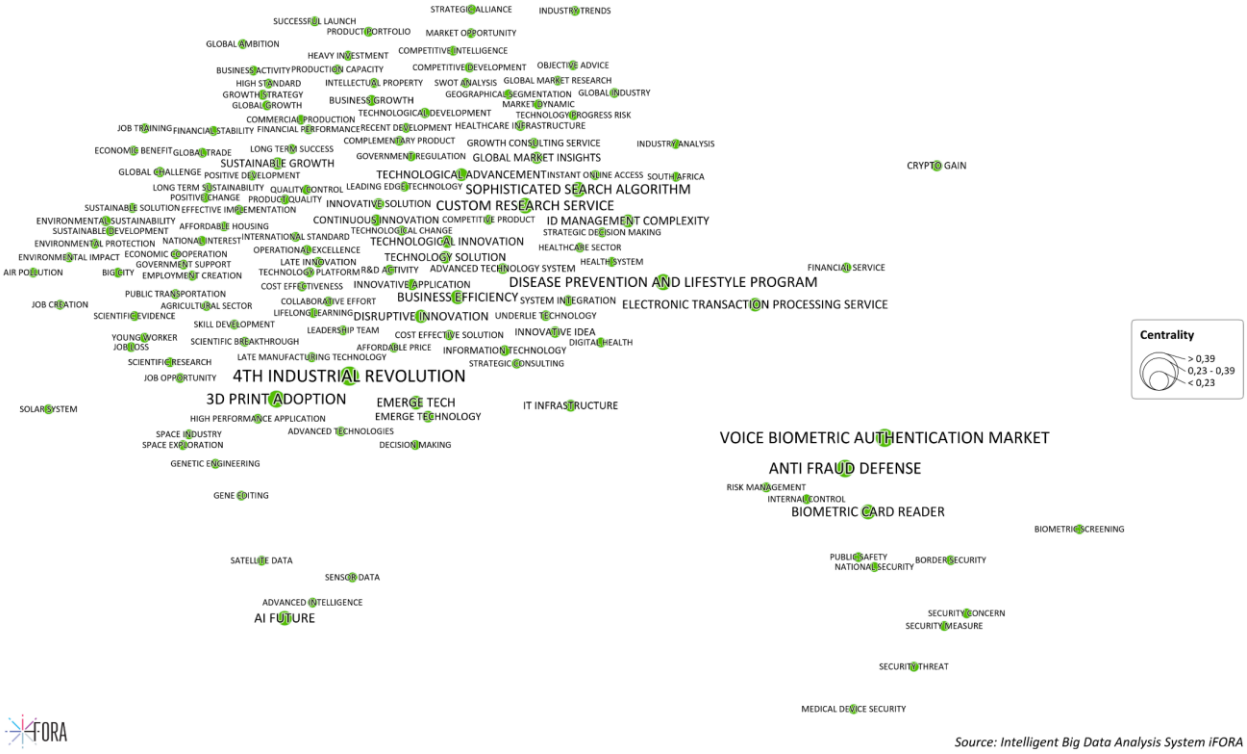

Figure 2.31. Cluster map. Industry 4.0

The cluster map shows that topics with the greatest centrality on Industry 4.0 are:

- 4TH INDUSTRIAL REVOLUTION
- VOICE BIOMETRIC AUTHENTICATION MARKET
- ANTI FRAUD DEFENSE
- 3D PRINT ADOPTION
- DISEASE PREVENTION AND LIFESTYLE PROGRAM
- CUSTOM RESEARCH SERVICE
- SOPHISTICATED SEARCH ALGORITHM
- BIOMETRIC CARD READER
- AI FUTURE
- BUSINESS EFFICIENCY

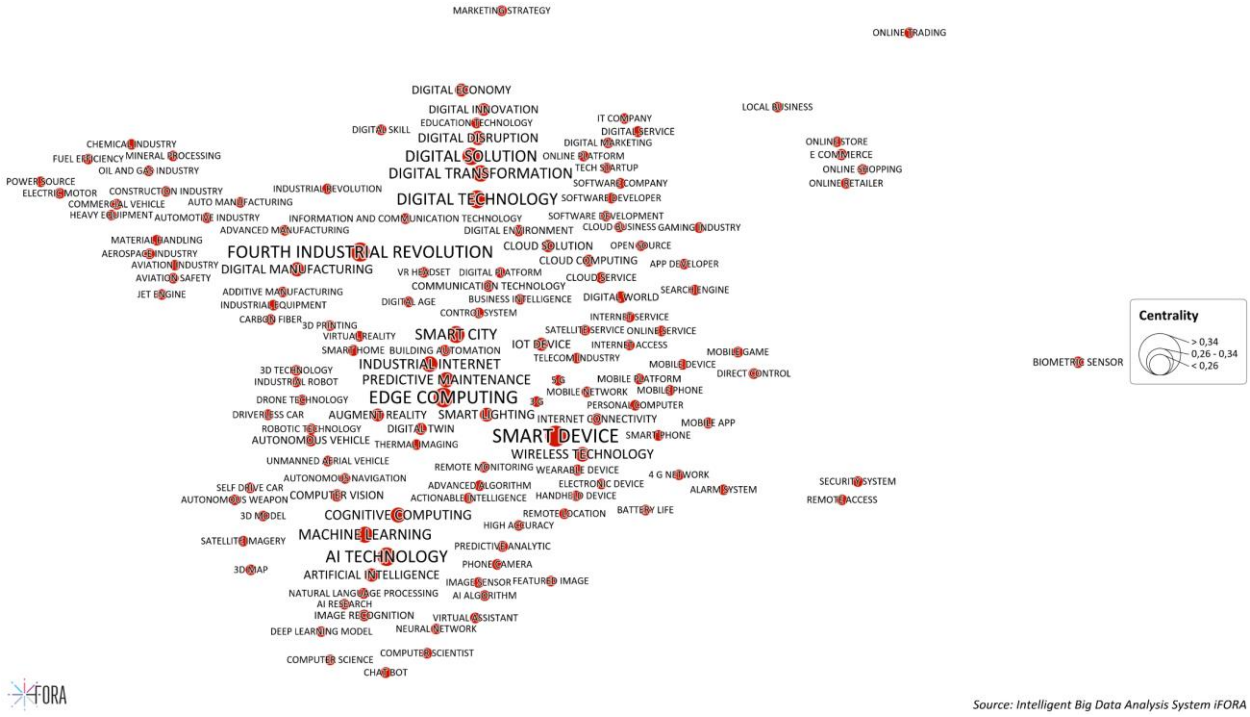

Figure 2.32. Cluster map. Technology Adoption & Industrial upgrade

The cluster map shows that topics with the greatest centrality on Technology Adoption & Industrial upgrade are:

- SMART DEVICE
- EDGE COMPUTING
- FOURTH INDUSTRIAL REVOLUTION
- AI TECHNOLOGY
- DIGITAL TECHNOLOGY
- DIGITAL SOLUTION
- SMART CITY
- DIGITAL TRANSFORMATION
- MACHINE LEARNING
- INDUSTRIAL INTERNET

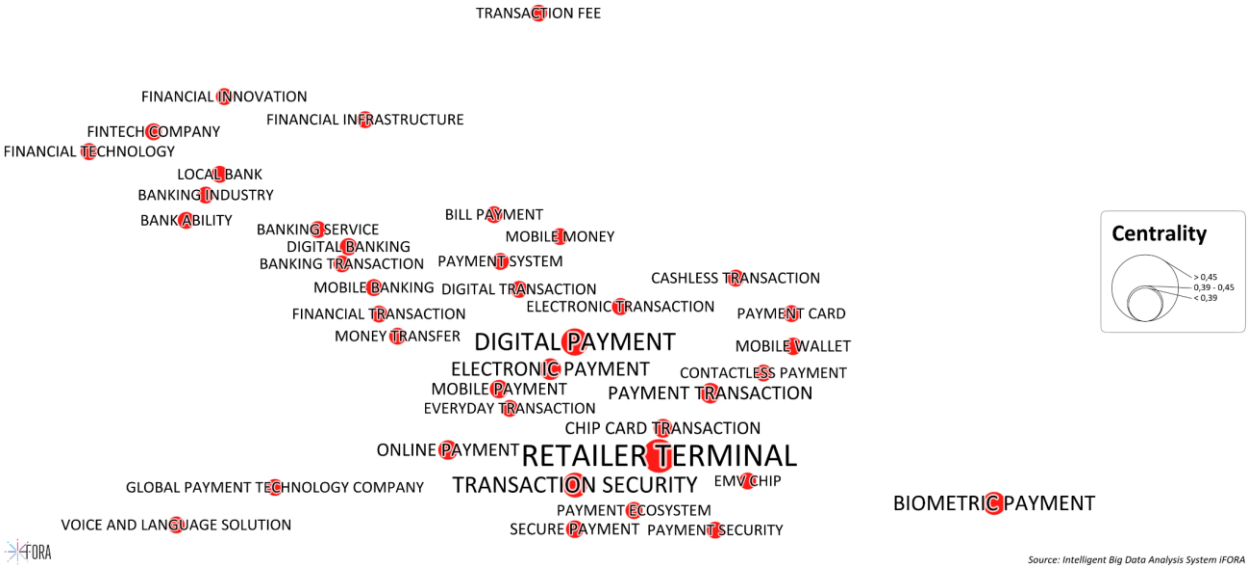

Figure 2.33. Cluster map. e-Finance

The cluster map shows that topics with the greatest centrality on e-Finance are:

- RETAILER TERMINAL
- DIGITAL PAYMENT
- TRANSACTION SECURITY
- BIOMETRIC PAYMENT
- ELECTRONIC PAYMENT
- PAYMENT TRANSACTION
- ONLINE PAYMENT
- CHIP CARD TRANSACTION
- MOBILE PAYMENT
- SECURE PAYMENT

Figure 2.34. Cluster map. Personal information security

The cluster map shows that topics with the greatest centrality on Personal information security are:

- BIOMETRIC AUTHENTICATION
- BIOMETRIC CAPABILITY
- BIOMETRIC DATA
- AUTHENTICATE IDENTITY
- ADAPTIVE AUTHENTICATION
- FINGERPRINT VERIFICATION
- BIOMETRIC IDENTITY
- BIOMETRIC SOLUTION
- UNIQUE VOICEPRINT
- BIOMETRIC VERIFICATION

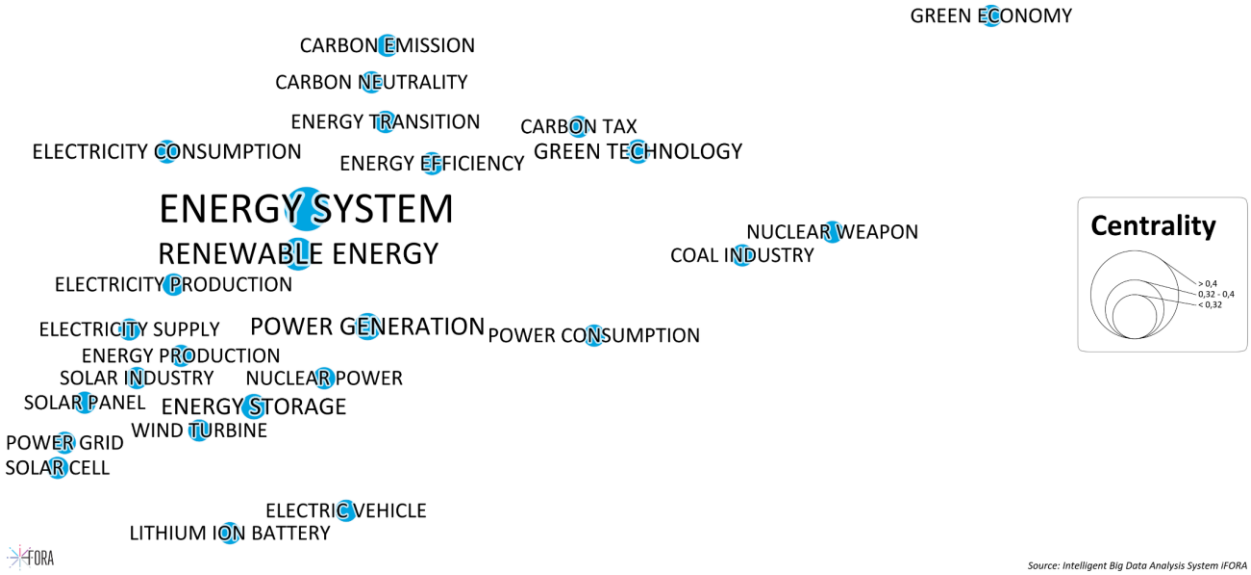

Figure 2.35. Cluster map. Renewable energy

The cluster map shows that topics with the greatest centrality on Renewable energy are:

- ENERGY SYSTEM
- RENEWABLE ENERGY
- POWER GENERATION
- ENERGY STORAGE
- GREEN TECHNOLOGY
- ELECTRICITY CONSUMPTION
- ENERGY EFFICIENCY
- CARBON EMISSION
- ENERGY TRANSITION
- ELECTRICITY PRODUCTION

2.4 Education for the future and the future of society

Figure 2.36 shows the semantic map for the Education for the future and the future of society domain.

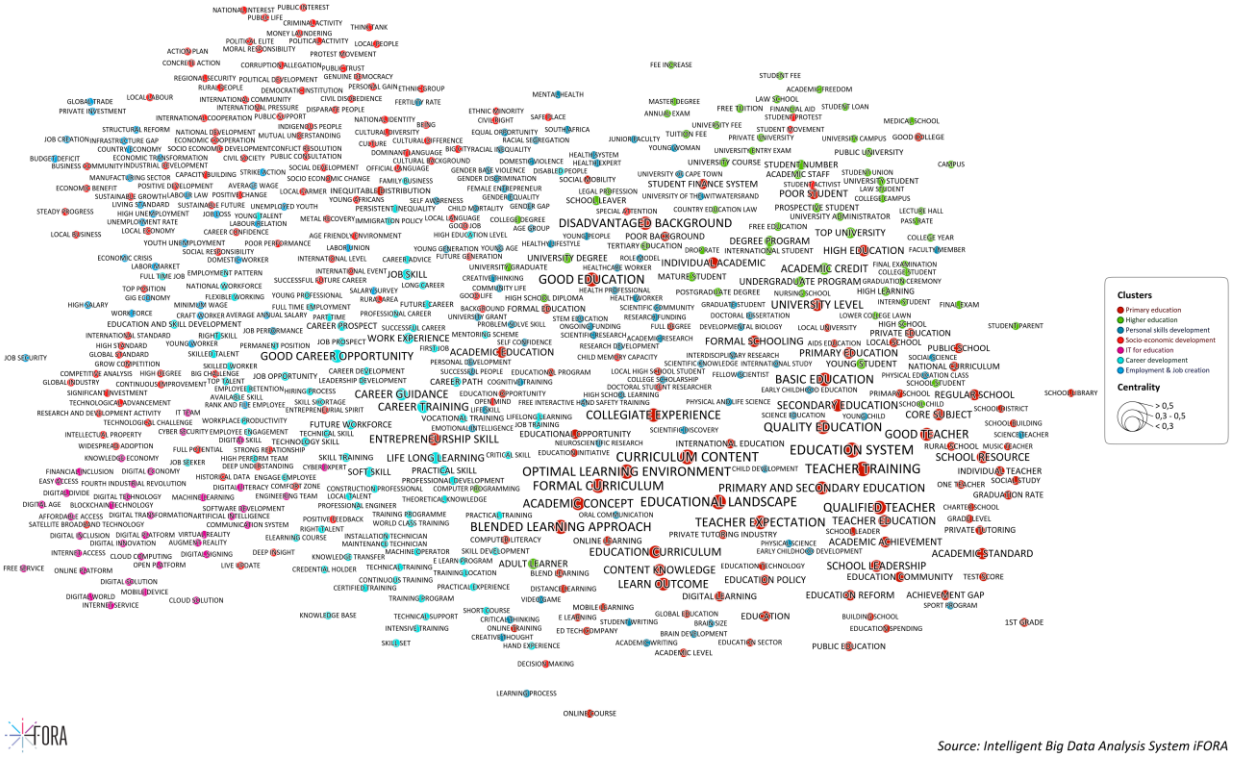

Figure 2.36. Semantic map

The semantic map shows that topics with the greatest centrality on Education for the future and the future of society are:

- EDUCATION SYSTEM
- CURRICULUM CONTENT
- TEACHER TRAINING
- EDUCATIONAL LANDSCAPE
- OPTIMAL LEARNING ENVIRONMENT
- FORMAL CURRICULUM
- BLENDED LEARNING APPROACH
- GOOD EDUCATION
- QUALITY EDUCATION
- TEACHER EXPECTATION

The points on the map are combined into one group, which shows thematic consistency of Education for the future and a high level of interconnection of the key topics of the direction with each other.

The semantic analysis of the domain revealed seven topics covering the key issues under the Education for the future and the future of society domain:

1. Higher education
2. Socio-economic development
3. Primary education
4. Employment and job creation
5. IT for education
6. Career development
7. Personal skills development

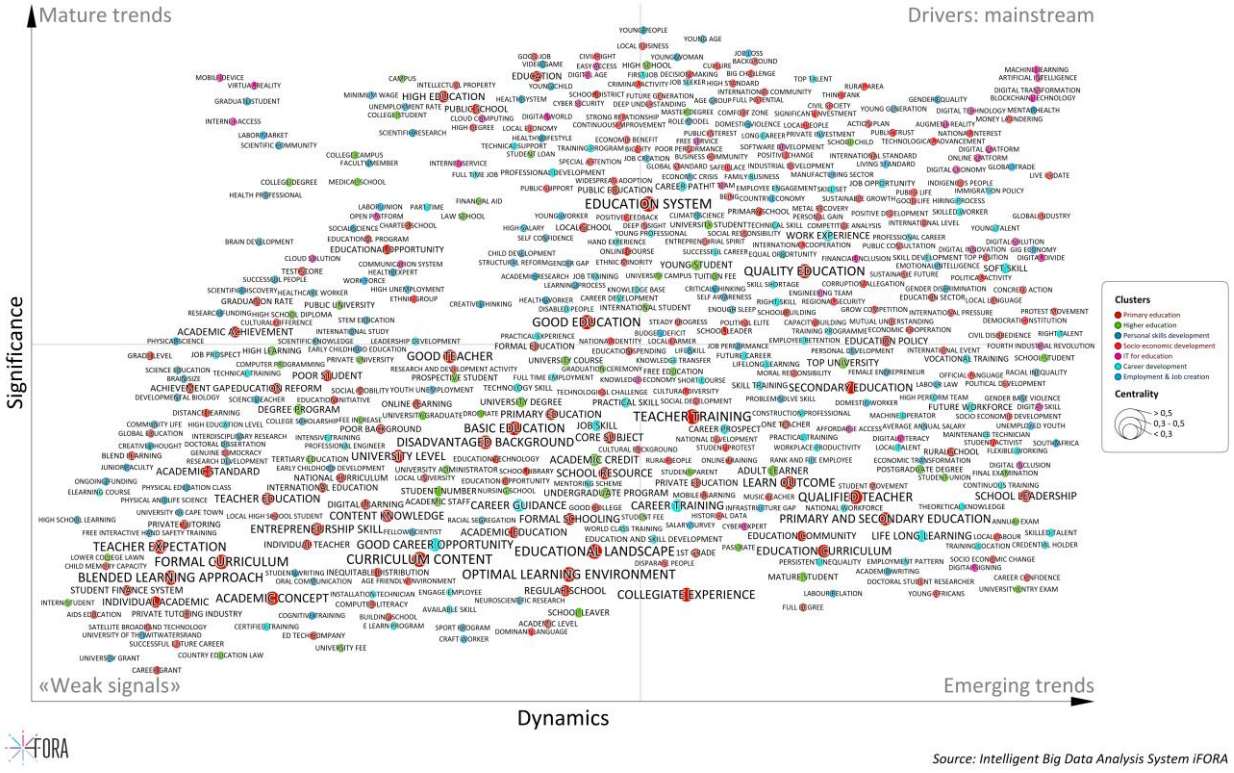

Figure 2.37. Trend map

The trend map shows that topics with the greatest centrality among drivers (mainstream) are:

- EDUCATION SYSTEM
- QUALITY EDUCATION

- WORK EXPERIENCE

Topics with the greatest centrality among mature trends are:

- GOOD EDUCATION
- HIGH EDUCATION
- ACADEMIC ACHIEVEMENT

Topics with the greatest centrality among emerging trends are:

- TEACHER TRAINING
- QUALIFIED TEACHER
- COLLEGIATE EXPERIENCE

Topics with the greatest centrality among "weak signals" are:

- CURRICULUM CONTENT
- EDUCATIONAL LANDSCAPE
- OPTIMAL LEARNING ENVIRONMENT

The topics are evenly spaced in all quadrants except for the "Mature trends" quadrant. The most central topics are located at the bottom of the trend map, which indicates that the area "Education for the future and the future of society" is currently at a stage of development and has not yet reached maturity and stability.

Figures 2.38 and 2.39 illustrate the global and South African matrices for the clusters of the Education for the future and the future of society domain and the indicators/priority areas for development.

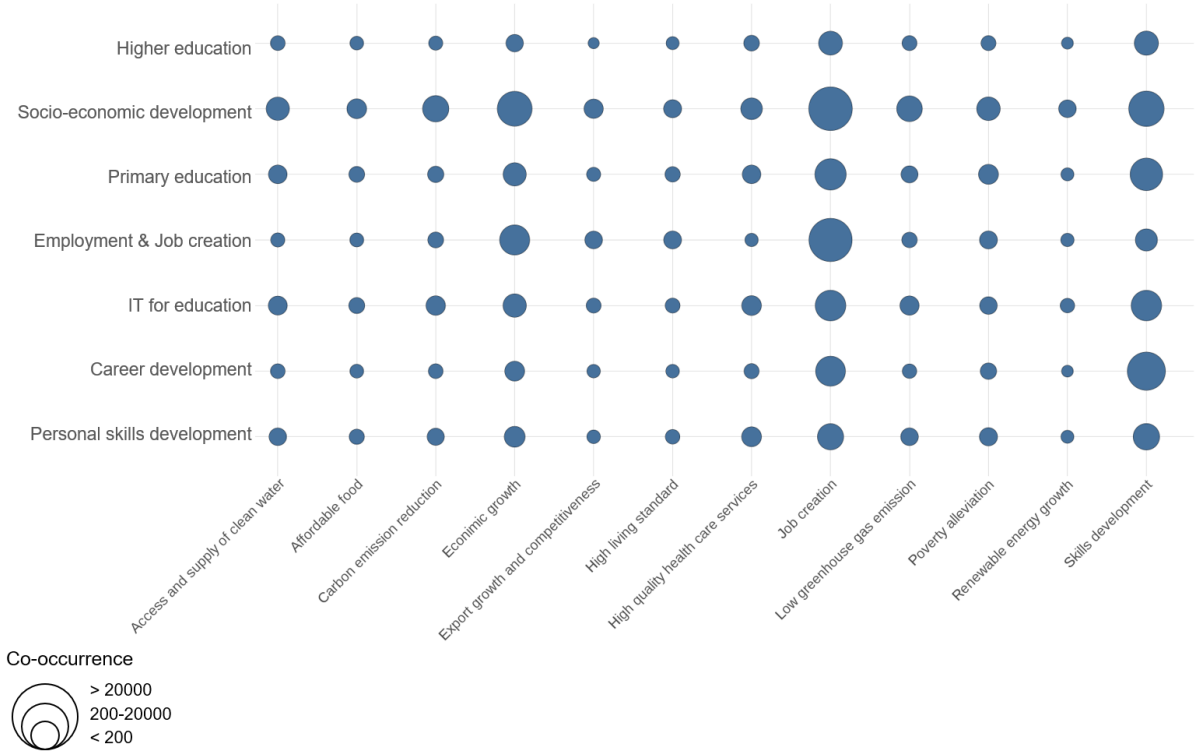

Figure 2.38. Clusters matrix: 7 clusters and 12 indicators (in all documents)

The matrix, built on the analysis of all documents around the world, shows that the most connected clusters and indicators are:

- Socio-economic development and Job creation.
- Employment.
- Job creation and Job creation.
- Career development and Skills development.
- Socio-economic development and Skills development.
- Socio-economic development and Economic growth.
- Employment.
- Job creation and Economic growth.

Clusters with the greatest connection with most indicators are Socio-economic development and Employment, Job creation. The most important indicators are Job creation, Skills development, and Economic growth.

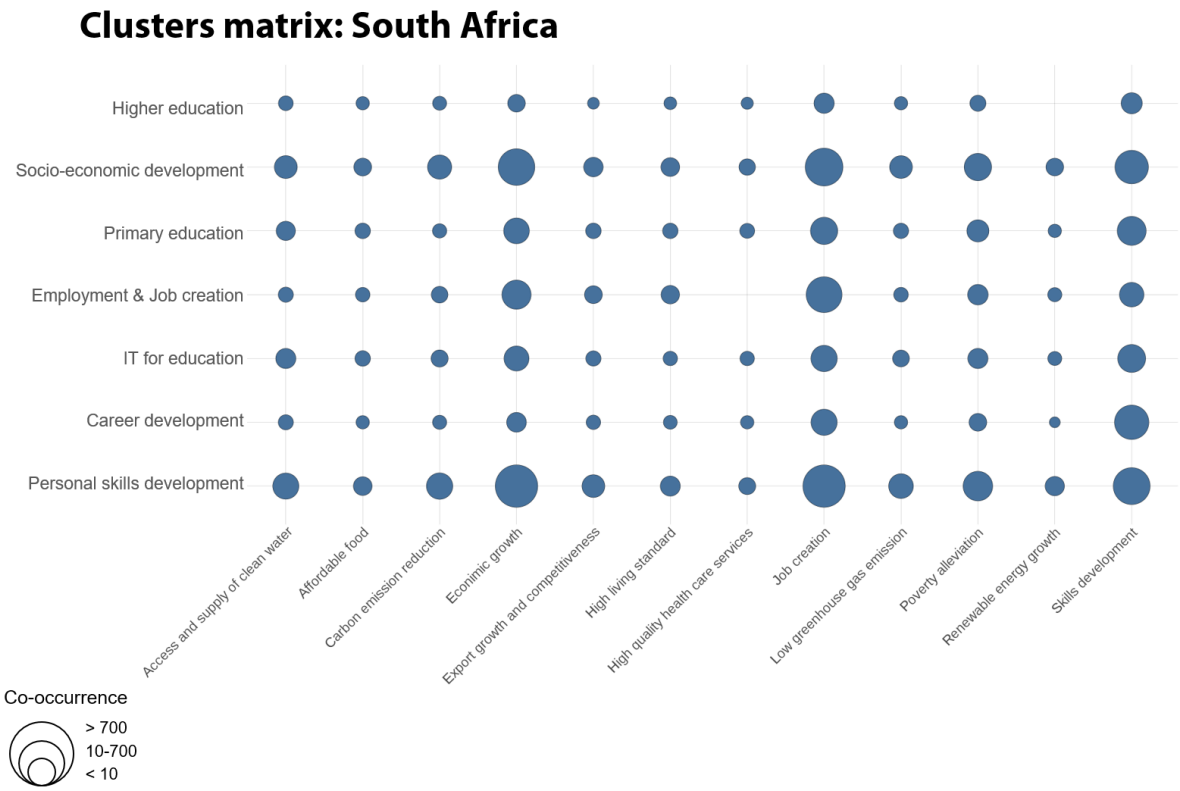

Figure 2.39. Clusters matrix: 7 clusters and 12 indicators (in documents that mention South Africa)

The matrix, built on the analysis of documents that mention South Africa, shows that in addition to the obvious and natural direct intersections such as Personal skills development and Skills development the most connected clusters and indicators are:

- Socio-economic development and economic growth are highly interlinked with each other. Socio-economic development is also possible with skills development, job creation and employment in the country. More jobs will help for poverty alleviation.
- IT for education is crucial for getting highly qualified workforce ready for aforementioned high-tech industrialisation.
- In parallel, personal skills need to be development for the next generation economic growth based in sustainable development and circular economy.

Clusters with the greatest connection with most indicators are Personal skills development, Socio-economic development and Employment, Job creation. The most important indicators are Economic growth, Job creation and Skills development. Cluster "Personal skills development" is

more relevant according to the analysis of documents that mention South Africa compared to all documents as well as the "Economic growth" indicator.

Figures 2.40 to 2.46 present the clusters of the Education for the future and the future of society domain.

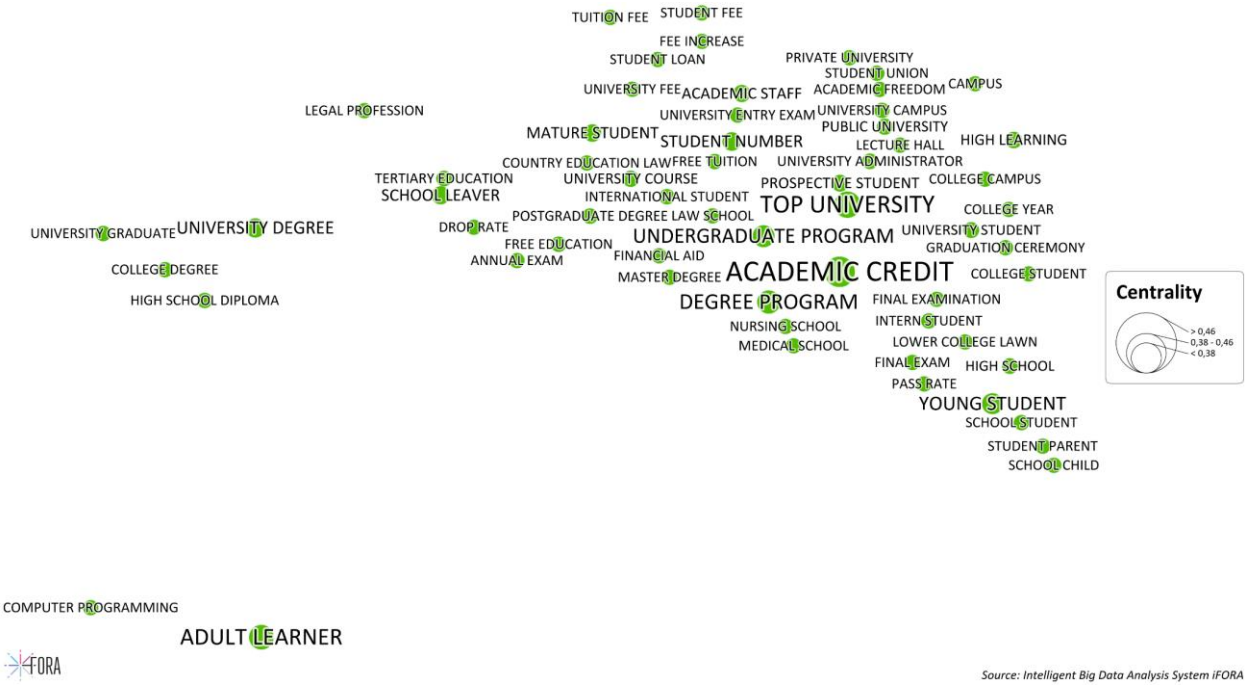

Figure 2.40. Cluster map. Higher education

The cluster map shows that topics with the greatest centrality on Higher education are:

- ACADEMIC CREDIT
- TOP UNIVERSITY
- ADULT LEARNER
- DEGREE PROGRAM
- UNDERGRADUATE PROGRAM
- YOUNG STUDENT
- UNIVERSITY DEGREE
- STUDENT NUMBER
- SCHOOL LEAVER
- MATURE STUDENT

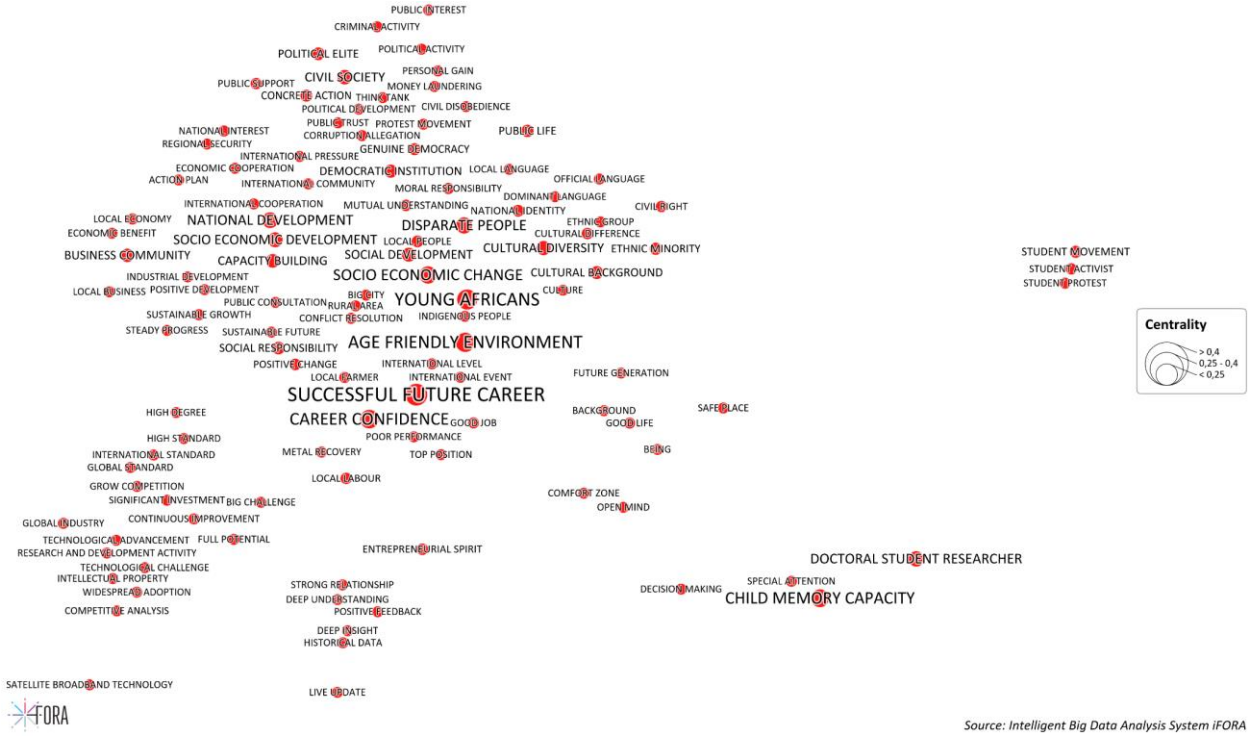

Figure 2.41. Cluster map. Socio-economic development

The cluster map shows that topics with the greatest centrality on Socio-economic development are:

- SUCCESSFUL FUTURE CAREER
- YOUNG AFRICANS
- AGE FRIENDLY ENVIRONMENT
- CAREER CONFIDENCE
- CHILD MEMORY CAPACITY
- SOCIO ECONOMIC CHANGE
- DISPARATE PEOPLE
- NATIONAL DEVELOPMENT
- DOCTORAL STUDENT RESEARCHER
- SOCIO ECONOMIC DEVELOPMENT

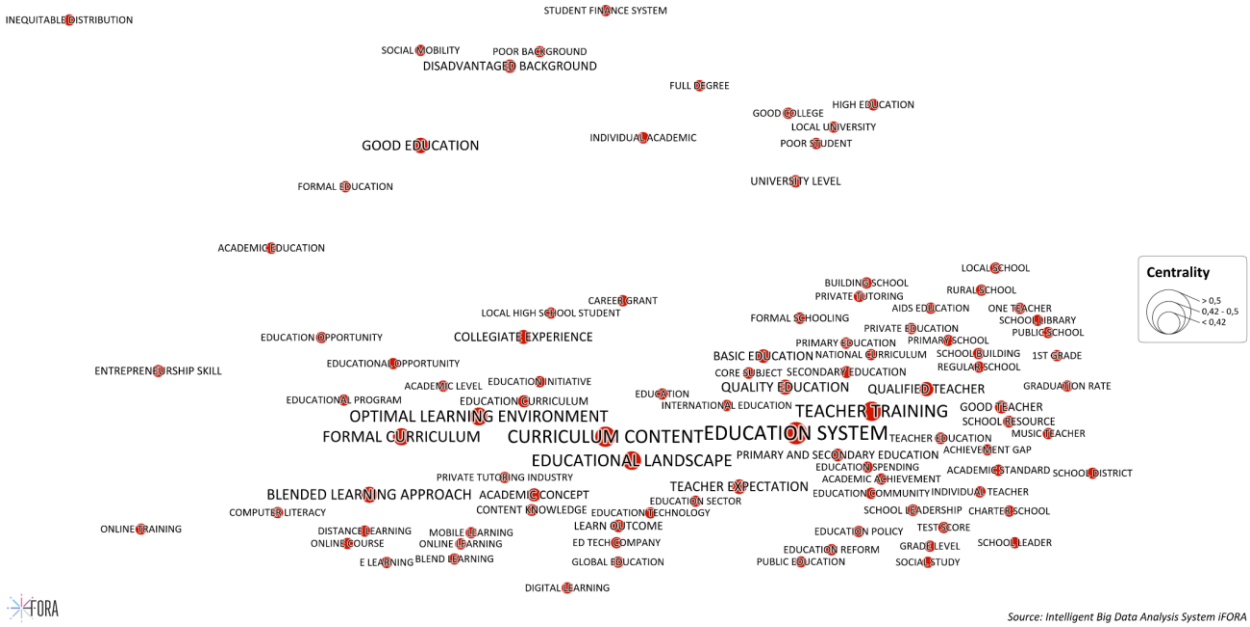

Figure 2.42. Cluster map. Primary education

The cluster map shows that topics with the greatest centrality on Primary education are:

- EDUCATION SYSTEM
- CURRICULUM CONTENT
- TEACHER TRAINING
- EDUCATIONAL LANDSCAPE
- OPTIMAL LEARNING ENVIRONMENT
- FORMAL CURRICULUM
- BLENDED LEARNING APPROACH
- GOOD EDUCATION
- QUALITY EDUCATION
- TEACHER EXPECTATION

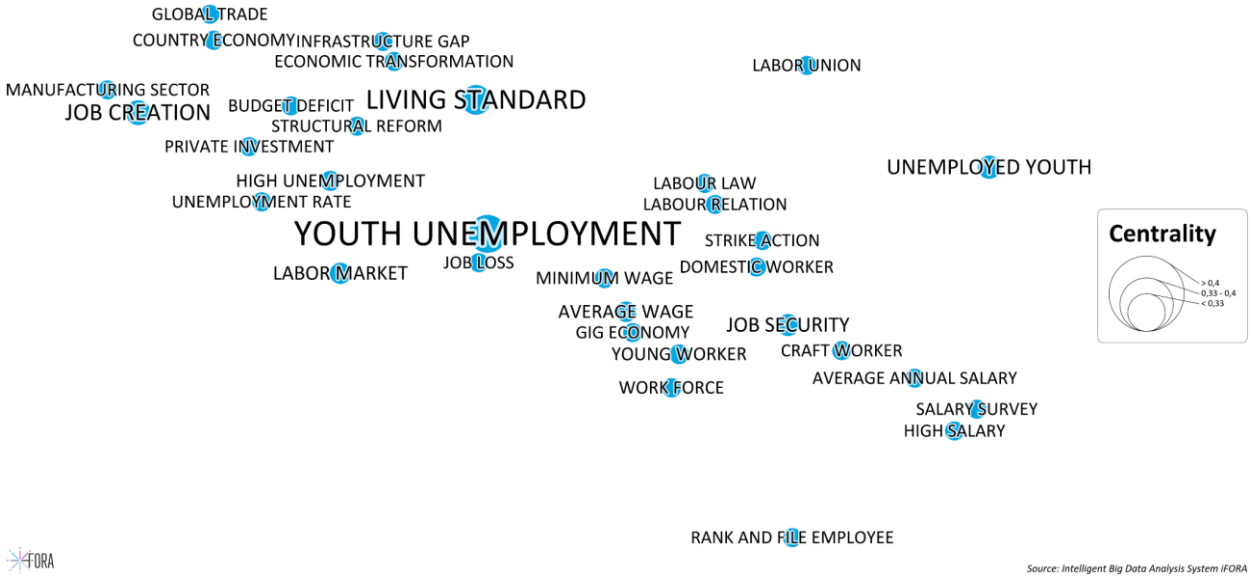

Figure 2.43. Cluster map. Employment & Job creation

The cluster map shows that topics with the greatest centrality on Employment and Job creation are:

- YOUTH UNEMPLOYMENT
- LIVING STANDARD
- JOB CREATION
- UNEMPLOYED YOUTH
- JOB SECURITY
- LABOR MARKET
- AVERAGE WAGE
- HIGH UNEMPLOYMENT
- YOUNG WORKER
- MINIMUM WAGE

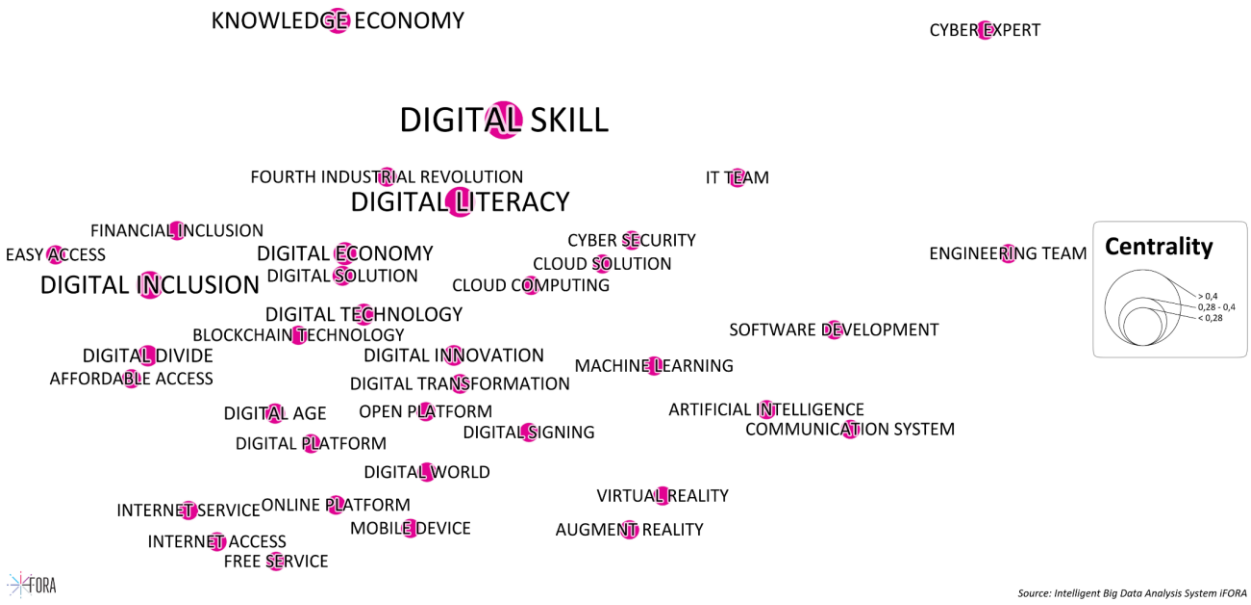

Figure 2.44. Cluster map. IT for education

The cluster map shows that topics with the greatest centrality on IT for education are:

- DIGITAL SKILL
- DIGITAL LITERACY
- DIGITAL INCLUSION
- KNOWLEDGE ECONOMY
- DIGITAL ECONOMY
- DIGITAL TECHNOLOGY
- DIGITAL DIVIDE
- DIGITAL INNOVATION
- DIGITAL AGE
- DIGITAL SOLUTION

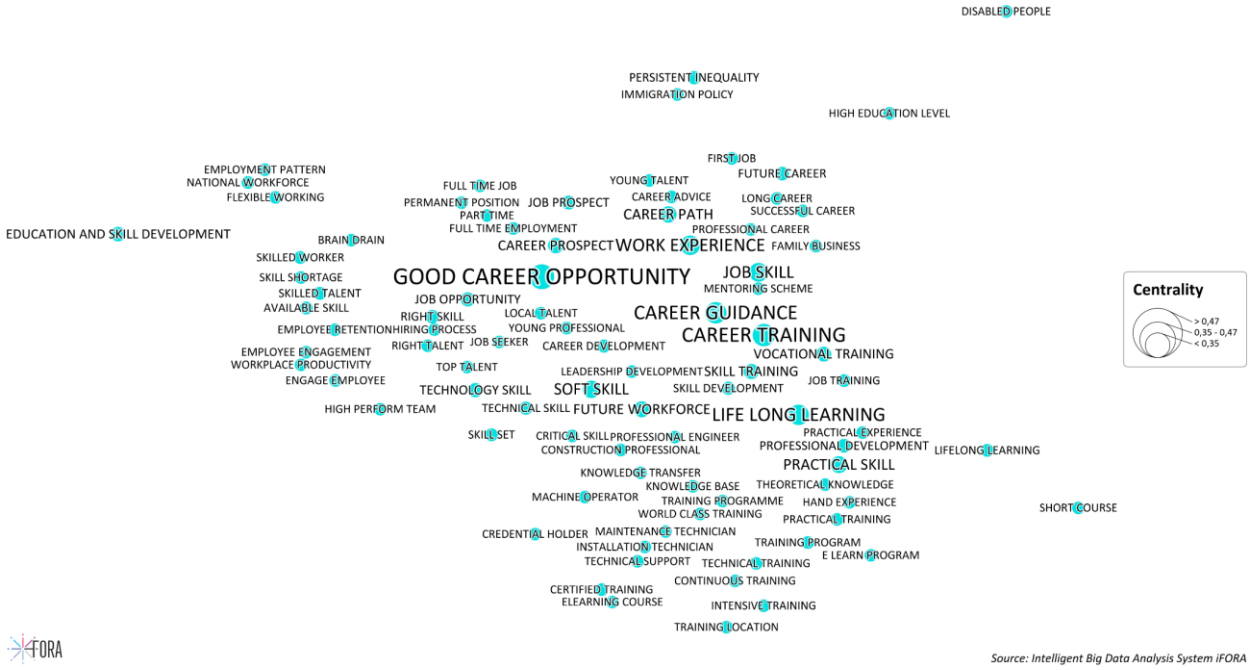

Figure 2.45. Cluster map. Career development

The cluster map shows that topics with the greatest centrality on Career development are:

- GOOD CAREER OPPORTUNITY
- CAREER TRAINING
- CAREER GUIDANCE
- LIFELONG LEARNING
- WORK EXPERIENCE
- JOB SKILL
- SOFT SKILL
- PRACTICAL SKILL
- CAREER PATH
- FUTURE WORKFORCE

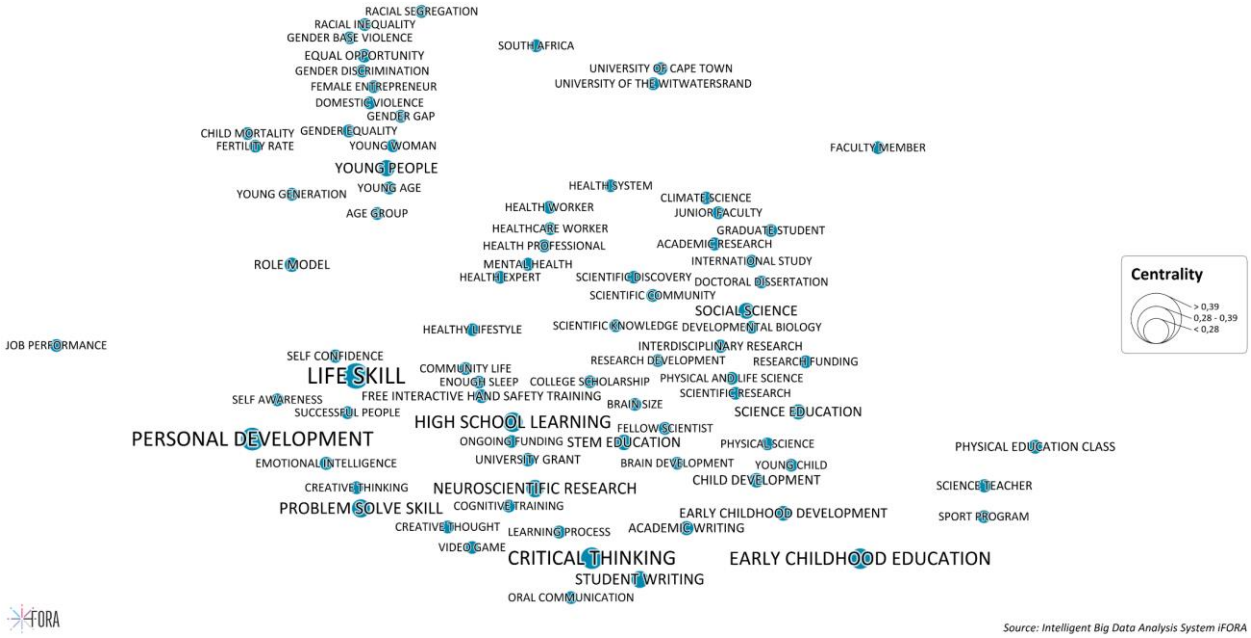

Figure 2.46. Cluster map. Personal skills development

The cluster map shows that topics with the greatest centrality on Personal skills development are:

- LIFE SKILL
- PERSONAL DEVELOPMENT
- CRITICAL THINKING
- EARLY CHILDHOOD EDUCATION
- HIGH SCHOOL LEARNING
- PROBLEM SOLVE SKILL
- NEUROSCIENTIFIC RESEARCH
- STUDENT WRITING
- YOUNG PEOPLE
- SOCIAL SCIENCE

3 KEY STATISTICS OF R&D SECTOR AND SCIENTOMETRIC ANALYSIS

3.1. Methodology

The comprehensive scientometric analysis of research landscape in South Africa is presented in terms of: level of the country's publication activity and its contribution to the global knowledge generation; thematic structure of publications, their scientific specializations; quality of articles measured by citation indicators; similarity of thematic structures of publications; international research collaboration profiles; and finally closeness and relative influence of each country in collaboration with other countries.

Key indicators of financial and human resources of R&D sector in South Africa was derived from UNESCO Institute of Statistic database (section "Science, technology and innovation"). Last update of UNESCO dataset is June 2020. For OECD and EU-28 countries in total the data was derived from OECD Main Science and Technology Indicators (OECD MSTI) database (updated at August 2020). The following indicators was used for the analysis:

- Number of researchers in full-time equivalent (measured in thousands persons years);
- Volume of gross expenditures on research and developments (GERD) (measured in billions US dollars (USD) in purchasing power parity (PPP));
- Ratio of GERD to GDP (measured in per cents);
- Volume of GERD per one researcher FTE (measured in thousands USD PPP).

For the four above-mentioned indicators South Africa was compared with leading countries in statics for the year 2018 (or the last available year with data) and in dynamics with Sub-Saharan Africa countries, global level and upped middle income countries. Key indicators of financial and human resources of R&D sector in South Africa are analysed in subsection 3.2.

Building on the analysis for our previous report "South Africa Science and Technology Foresight for 2030", we take Scopus as a database for our bibliometric analysis. Scopus is one of the largest science citation databases worldwide. As of the start of February 2021, Scopus indexed more than 81.5 mln documents. Timespan of the analysis covers the period of 2000-2019 since the year 2020 is not yet complete in Scopus database. As publications in all our calculations, we take (unless otherwise indicated) documents like articles, reviews, and conference papers indexed in Scopus. A publication is considered to belong to a certain country if at least one of its authors is affiliated with this country. Different approaches are used to visualize data in form of illustrative tables and charts. A wide range of bibliometric indicators was used for analysis that allows demonstrating some of the key trends in the development of research landscape in South Africa.

For the **comparison of publication activity of South Africa with other countries** we use the following list of indicators:

- Number of publications of a country in Scopus, thousand units;
- Share of a country in the global number of publications, %;
- Position of a country in the global rankings of countries by number of publications, place.

Analysis of basic indicators of publication activity of South Africa is done it subsection 3.3.

Citation indictors were derived from Scopus SciVal – electronic analytical tool based on Scopus data[1]. In our analysis we used citation indicators like:

- Field-Weighted Citation Impact (FWCI), points;
- Share of publications in Q1 Journal Quartile by CiteScore in all publications of a country, %;
- Share of publications in Top 1% Citation Percentiles in all publications of a country, %.

Subsection 3.4 is devoted to the analysis of citation indicators of South Africa in Scopus database.

According to methodology, derived by Scopus, Field-Weighted Citation Impact (FWCI) for country indicates how the number of citations received by an country's publications compares with the average number of citations received by all other similar publications in the data universe: how do the citations received by this country's publications compare with the world average? Field-Weighted Citation Impact of "World", or the entire Scopus database, is 1.00[2]" FWCI of more than 1.00 indicates that the country's publications are cited more than would be expected based on the global average. E.g. FWCI 1.65 for country A means that country's A publications are cited 65% more than the world average. FWCI of less than 1.00 indicates that the country's publications are cited less than would be expected based on the global average. E.g. FWCI 0.63 for country A means that country's A publications are cited 27% less than the world average.

Publications in Q1 Journal Quartile by CiteScore are publications in journals that are included in top 25th percentile (top 25%), first quartile or Quartile 1 (Q1) of journals by the value of CiteScore in at least one of Scopus subject category of a journal[3]. CiteScore according to Scopus

[1] See more on SciVal on: https://www.elsevier.com/solutions/scival
[2] More description of methodology of FWCI calculation as well as formulas of FWCI can be found at: https://service.elsevier.com/app/answers/detail/a_id/28190/supporthub/scival/p/10961/
[3] See more on breaking of publications by Journal Quartiles in Scopus at: https://service.elsevier.com/app/answers/detail/a_id/29508/supporthub/scival/

methodology "is a simple way of measuring the citation impact of serial titles such as journals. Serial titles are defined as titles, which publish on a regular basis (i.e. one or more volumes per year). Calculating the CiteScore is based on the number of citations to documents (articles, reviews, conference papers, book chapters, and data papers) by a journal over four years, divided by the number of the same document types indexed in Scopus and published in those same four years"[4]. CiteScore 2019, the most recent CiteScore metrics for Scopus-indexed journals calculated in May 2020, counts the citations received in 2016-2019 to articles, reviews, conference papers, book chapters, and data papers published in 2016-2019, and divides this by the number of these documents published in 2016-2019.

Publications in Top 1% Citation Percentiles in SciVal indicates the extent to which a country's publications are presented in the most-cited percentiles of all publications in Scopus: how many publications of a country are in the top 1%, of the most-cited publications[5].

Indicators of thematic structure for South Africa include:

- Number of South Africa publications in specific Scopus subject area in 2019, units;
- Share of a specific Scopus subject area in all South Africa publications in 2019 and for 2015-2019, %
- Position of South Africa in the global ranking of countries by number of publications in a specific Scopus subject area in 2019;
- Ratio of publications of South Africa to the number of publications of global leader by number of publications in specific Scopus subject areas in 2019, %;
- Share of a specific Scopus subject area in the total number of publications of the world (all Scopus-indexed publications) for 2015 – 2019, %;
- Relative comparative advantage (RCA) index value of South Africa for 2015 – 2019, points.

Relative comparative advantage (RCA) index was calculated for South Africa that reflects the degree of its S&T specialization in a given Scopus subject area.

For a given country (j) and a given subject area (i) Revealed comparative advantages index (RCA) index is calculated as follows: $RCA_{subjarea\ i\ country\ j} = \frac{Share_{subjarea\ i\ country\ j}}{Share_{subjarea\ i\ world}}$

where $Share_{subjarea\ i\ country\ j}$ – is the share of publications on subject area i (i = 1, … , 27) in the total number of publications of a specific country j in the Scopus database; - $Share_{subjarea\ i\ world}$ - is the share of publications on subject area i (i = 1, … , 27) in the global number of publications in the Scopus database.

[4] Detailed description of CiteScore methodology

[5] https://service.elsevier.com/app/answers/detail/a_id/28193/supporthub/scival/p/10961/

Subject areas where RCA index value is higher than 1.0 are considered as areas of research specialization of South Africa. Subject areas with the RCA index above 1.5 are considered as the key areas of scientific specialization of the South Africa. As shown in [Shashnov and Kotsemir, 2018], in bibliometric studies relative (revealed) comparative advantages index is also called as "scientific specialization index" or "index of scientific specialization" or "relative (scientific) specialization index". Thematic structure of Scopus-indexed publications of South Africa is studied in subsection 3.5.

Finally, **indicators of international research collaboration** include:

- Number of internationally collaborated publications (ICPs) in South Africa, units;
- Shares of ICPs in the total number of publications of South Africa, % (for all publications of South Africa and for all Scopus subject area);
- Number of joint publications of South Africa with a specific country, units;
- Share of a country in all (ICPs) of South Africa, %;
- Growth of number of joint papers of South Africa with a specific country in 2019 to 2000, times;
- Number of internationally collaborated publications of South Africa in a specific Scopus subject area, units;
- Share of a specific Scopus subject area in all internationally collaborated publications of South Africa, %.

Subsection 3.6 focuses on the analysis of international research collaboration of South Africa in Scopus.

Bibliometric analysis on four domains of S&T development of South Africa (Health Innovation, Circular Economy, Education, High-tech Industry) was derived from Microsoft Academic Graph (MAG) database. As of start of February 2021 Microsoft Academic Graph indexes more than 250 ml of publications from 49 thousands journals and 4500+ conferences[6]. Microsoft Academic Graph (MAG) is a heterogeneous information storage platform containing both the texts of scientific publications and the citation relationships between these publications, as well as metadata: names of authors, institutions, journals, conferences and topics of research (the total number of topic in MAG is currently over 739 thousands). Data on citations in MAG is derived from Crossref metadata search mechanism. Further, the data on publications and citations from MAG was processed by iFORA to receive time series on number of publications and citations on each of four South Africa domains on country level. Corpuses of publications on each of four

[6] See more on Microsoft Academic Graph on: https://academic.microsoft.com/home

domains in MAG database was derived by search of keywords related with each specific domain in titles and abstracts of MAG-indexed publications. Processing of MAG-indexed publications by iFORA was performed in December 2019 so the data for 2018 and 2019 in tables is incomplete. For each of four South Africa S&T development domains we calculate the following indicators from Microsoft Academic Graph Database:

- Number of publication of a country in a specific domain, thousands units;
- Share of country in the global number of publications in a specific domain, %;
- Position of a country in the global ranking by number of publications in a specific domain (among top-50 countries by number of publications for 2000-2019);
- Share of a country in the global number of citation on publications in a specific domain, %;
- Position of a country in the global ranking by number of citations received on publications in a specific domain (among top-50 countries by number of publications for 2000-2019);
- Citation impact of country in a specific domain relative to world, points.

For each specific domain we show publication activity indicators and citation indicators for leading countries by number of publications/citation received in 2019 and South Africa.

Citation impact of country relative to world is a ratio of citation impact of a specific country to world average citation impact in the corpus of MAG-indexed publications on a specific domain.. Citation impact of country is an average number of citations received by publications of this country in a specific year. Tables with bibliometric analysis of MAG-indexed publications of South Africa in four domains of S&T development of a country (Health Innovation, Circular Economy, Education, High-Technology Industry) are provided in Section 3.7.

3.2. Financial and Human resources of R&D sector in South Africa

When South Africa's overall scientific and technological potentials assessed, it is seen that the country still has considerable progress to make. There is an urgent need to increase the R&D intensity of the country. By number of researchers (29.5 thousands person-years in full time equivalent (FTE) in 2017) South Africa is far behind leading countries (compare 1 866.1 in 2018 ths person-years for China, 1 434.4 in 2017 for USA, 678.1 for Japan in 2018). Meanwhile South Africa is among the leaders in Africa by number of researchers: 67.6 ths. person-years in Egypt in 2017; 33.9 – in Algeria (2017).

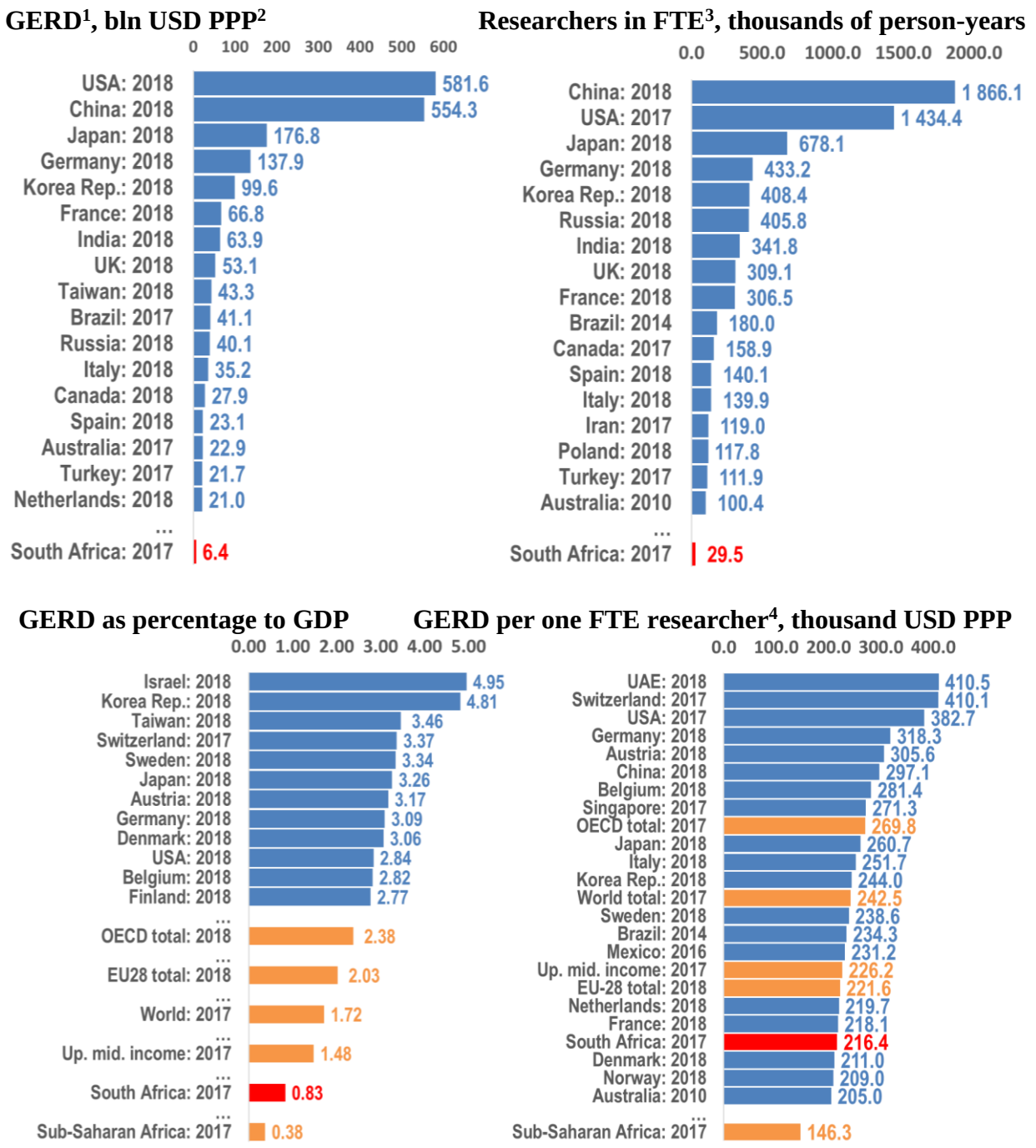

Figure 3.1. Key R&D expenditures and R&D personnel indicators for South Africa in comparison with best benchmark countries in 2018 or last year with available data

Notes. 1. GERD is Gross expenditures on Research and development; 2. PPP is Purchasing power parity. 3. FTE is Full-time equivalent. 4. GERD per one FTE researcher is calculated for countries with at least 10 000 person-years of researchers in full time equivalent. 5. To maintain continuity with our previous analysis we take EU-28 (taking UK as a member of EU). 6. For China we take data for Mainland China.

Source: Derived from (Shashnov and Kotsemir 2018) and updated with the latest available data with focus on South Africa. Calculated by authors using UNESCO Institute of Statistic database (section "Science, technology and innovation"). Last update: June 2020.

By volume of Gross expenditures on research and development (GERD): 6.4 bln USD PPP in South Africa also stays far behind from the leading countries (581.6 in USA in 2018, 554.3 in China in 2018). By GERD volume South Africa is among the leaders in African continent. The volume of GERD in Egypt was 8.8 bln USD PPP in 2017, in Algeria – 3.4.

By one of key indicators for R&D – Gross Expenditure on Research and Development – GERD as percentage of GDP South Africa is also far behind leading countries – 0.83%, whereas Israel has 4.95% and Korea Rep – 4.81%. GERD-to-GDP ratio in South Africa is much lower than in OECD (2.38%), EU28 (2.03%) and global level (1.73%) and upper middle income (1.48%) but much higher than the total level for Sub-Saharan Arica (0.38%).

Volume of GERD per one researcher FTE in South Africa (216.4 ths USD PPP in 2017) was comparable with leading countries, EU-28 (221.6), upper middle income countries (226.2) slightly lower that global level (242.6) and OECD level (269.8) and higher than in Sub-Saharan Africa countries.

Table 3.1. Key R&D expenditures and R&D personnel in South Africa in comparison to Sub-Saharan Africa countries, upper middle-income countries and the world in 1997 – 2019

Indicators	1997	2001	2005	2010	2015	2016	2017
Number of researchers (FTE) in South Africa	8 533.0	14 182.0	17 303.0	18 719.6	26 159.4	27 656.2	29 515.2
Share of South Africa in the total number of researchers in all countries from Sub-Saharan Africa, %	25.2	33.0	33.5	27.6	29.1	29.2	29.5
GERD in bln. current PPP$ in South Africa	1.80	2.61	4.05	4.43	5.83	6.10	6.39
Share of South Africa in the total GERD volume in all countries from Sub-Saharan Africa, %	53.2	60.3	66.3	48.5	46.0	45.6	45.8
GERD as a percentage of GDP							
South Africa	0.58	0.72	0.86	0.74	0.80	0.82	0.83
Africa (Sub-Saharan)	0.31	0.35	0.37	0.36	0.37	0.38	0.38
Upper middle-income countries	0.57	0.70	0.84	1.13	1.41	1.45	1.48
World	1.42	1.54	1.53	1.62	1.69	1.69	1.72
GERD per researcher, FTE (in '000 current PPP$)							
South Africa	211.1	183.9	234.0	236.5	223.0	220.4	216.4
Africa (Sub-Saharan)	104.4	110.2	132.1	138.9	148.6	147.6	146.3
Upper middle-income countries	48.8	69.6	97.7	152.8	205.7	212.9	226.2
World	129.9	154.6	170.5	202.7	228.7	233.3	242.5
Researchers per million inhabitants (FTE)							
South Africa	198.5	311.2	361.4	365.5	472.3	492.0	517.7
Africa (Sub-Saharan)	57.3	65.4	70.8	81.2	93.9	96.0	99.0
Upper middle-income countries	536.9	559.9	670.9	873.5	1071.3	1112.3	1135.5
World	775.2	818.9	903.3	1018.4	1154.3	1173.6	1198.0

Source: Calculated by authors using UNESCO Institute of Statistic database (section "Science, technology and innovation"). Last update: June 2020.

South Africa in 1997 – 2017 takes 25% - 33% of all researchers form Sub-Saharan Africa countries. Table 3.1 presents the "contribution" of South Africa to the total volume in comparison with Sub-Saharan Africa, upper-middle income countries and the World. The data indicates:

- high contribution of South Africa to the total volume of GERD of Sub-Saharan Africa

- by GERD as a percentage of GDP South Africa is much higher than Sub-Saharan Africa but much lower than Upper middle-income countries and the global level

- by GERD per researcher, FTE South Africa is higher than Sub-Saharan Africa and comparable with Upper middle-income countries and the global level

- by "intensity" of Researchers per million inhabitants South Africa is much higher that Sub-Saharan Africa countries but more than two time lower than Upper middle-income countries and the global level.

3.3. Publication activity

Figure 3.2 shows the dynamics of publications in South Africa in Scopus for 2000 – 2019. The figure indicates that in average the highest year-to-year growth rate of number of publications was registered in 2008 – 2014. The highest growth of the share of South Africa in the global number of publications was registered in 2009 – 2016.

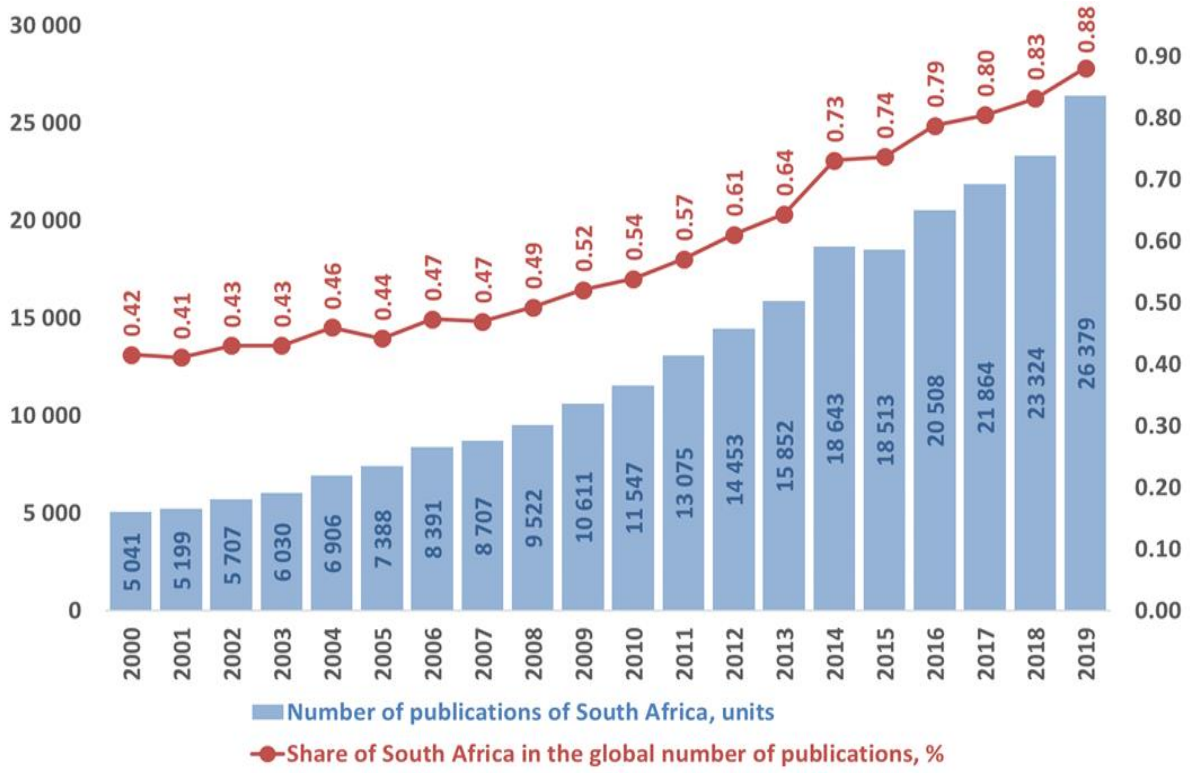

Figure 3.2. Dynamics of publications in Scopus (2000-2017) – (vertical axis indicates 1000 publications)

Source: Authors' calculations from data taken from Scopus database. Types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Table 3.2 shows the number of publications in different countries their shares in the global unmber of publications and positions in global science. It is seen that China[7] has made a significant progress in terms of the number of publications (13.04 times growth for the studies period) and jumped from 6th place in 2000 to the first place in 2014. The number of publications from South Africa remained rather modest.

[7] In all our calculations we take China as Mainland China since Hong Kong and Macao are counted as separate countries in the Scopus database.

Table 3.2. Key statistics of publication activity of leading countries in Scopus in 2000 – 2019

Country	Number of publications in Scopus, '000						Share in global number of publications in Scopus						Position in ranking of countries by number of publications						Growth of the number of publications 2019 to 2000, times
	2000	2005	2010	2015	2018	2019	2000	2005	2010	2015	2018	2019	2000	2005	2010	2015	2018	2019	
China	51.7	170.2	339.7	450.1	591.6	673.5	4.26	10.17	15.85	17.91	21.09	22.49	6	2	2	2	2	1	13.04
United States	353.6	463.9	517.1	567.6	592.8	606.0	29.14	27.72	24.13	22.58	21.14	20.23	1	1	1	1	1	2	1.71
United Kingdom	98.3	118.5	141.2	166.1	179.0	188.1	8.10	7.08	6.59	6.61	6.38	6.28	3	4	3	3	3	3	1.91
India	24.5	38.9	75.8	131.8	163.7	174.9	2.02	2.33	3.54	5.24	5.84	5.84	13	12	9	5	5	4	7.13
Germany	86.3	114.6	137.4	156.5	164.8	167.2	7.12	6.85	6.41	6.23	5.88	5.58	4	5	4	4	4	5	1.94
Japan	103.2	123.4	123.6	118.7	124.8	124.0	8.50	7.37	5.77	4.72	4.45	4.14	2	3	5	6	6	6	1.20
Italy	43.1	60.6	78.3	99.7	107.9	113.4	3.55	3.62	3.66	3.97	3.85	3.79	8	8	8	8	8	7	2.63
Russian Federation	34.5	39.6	39.5	66.2	100.8	110.0	2.85	2.36	1.84	2.63	3.60	3.67	9	11	15	13	9	8	3.19
France	61.3	78.4	97.4	108.8	110.5	108.4	5.05	4.68	4.55	4.33	3.94	3.62	5	6	6	7	7	9	1.77
Canada	43.4	64.9	81.0	92.2	99.6	104.9	3.58	3.88	3.78	3.67	3.55	3.50	7	7	7	9	10	10	2.42
Australia	29.2	42.4	60.9	83.4	92.9	100.3	2.41	2.53	2.84	3.32	3.31	3.35	11	10	11	10	11	11	3.43
Spain	30.0	45.9	66.8	81.1	88.2	93.1	2.47	2.74	3.12	3.23	3.15	3.11	10	9	10	11	12	12	3.10
South Korea	18.3	37.4	59.4	78.7	82.9	86.6	1.51	2.24	2.77	3.13	2.96	2.89	15	13	12	12	13	13	4.74
Brazil	15.2	26.2	48.6	66.0	77.9	81.1	1.26	1.57	2.27	2.63	2.78	2.71	17	15	13	14	14	14	5.32
Iran	1.9	8.2	29.4	44.1	57.0	63.0	0.15	0.49	1.37	1.75	2.03	2.10	48	33	20	16	15	15	33.94
Netherlands	24.7	34.1	44.5	52.2	56.1	58.7	2.04	2.04	2.08	2.08	2.00	1.96	12	14	14	15	16	16	2.37
Poland	15.0	24.4	30.2	41.5	47.9	47.6	1.23	1.46	1.41	1.65	1.71	1.59	18	18	19	17	17	17	3.18
Turkey	7.7	20.0	31.6	40.3	41.7	47.1	0.64	1.20	1.47	1.60	1.49	1.57	25	20	18	19	19	18	6.11
Indonesia	0.8	1.2	2.6	8.1	33.9	44.9	0.06	0.07	0.12	0.32	1.21	1.50	60	62	57	48	22	19	59.45
Switzerland	17.7	24.5	32.1	40.7	43.8	44.6	1.46	1.46	1.50	1.62	1.56	1.49	16	17	17	18	18	20	2.51
Sweden	19.1	23.3	28.1	36.4	39.4	41.4	1.58	1.39	1.31	1.45	1.40	1.38	14	19	21	21	20	21	2.16
Taiwan	13.5	25.4	39.4	36.8	34.7	36.8	1.12	1.52	1.84	1.46	1.24	1.23	19	16	16	20	21	22	2.72
Malaysia	1.7	3.4	15.4	26.9	32.5	35.6	0.14	0.20	0.72	1.07	1.16	1.19	49	46	28	23	23	23	20.72
Belgium	13.1	19.1	24.6	30.2	31.8	32.3	1.08	1.14	1.15	1.20	1.13	1.08	20	21	22	22	24	24	2.47
Denmark	9.9	12.3	16.7	24.3	26.6	27.9	0.82	0.73	0.78	0.97	0.95	0.93	22	25	24	24	25	25	2.82
Saudi Arabia	2.0	2.4	6.2	19.0	22.4	26.8	0.16	0.14	0.29	0.75	0.80	0.89	47	50	46	29	31	26	13.52
Portugal	4.4	8.2	15.0	21.9	24.1	26.6	0.36	0.49	0.70	0.87	0.86	0.89	37	32	31	27	27	27	6.02
South Africa	**5.0**	**7.4**	**11.5**	**18.5**	**23.3**	**26.4**	**0.42**	**0.44**	**0.54**	**0.74**	**0.83**	**0.88**	**36**	**37**	**36**	**32**	**30**	**28**	**5.23**
Mexico	6.6	11.0	15.2	19.9	23.8	25.9	0.54	0.66	0.71	0.79	0.85	0.87	29	28	29	28	29	29	3.96
Austria	9.0	13.5	18.0	22.8	24.1	25.4	0.74	0.81	0.84	0.91	0.86	0.85	24	23	23	26	26	30	2.82
Egypt	3.3	4.7	9.3	16.2	20.9	24.6	0.27	0.28	0.43	0.65	0.74	0.82	39	42	41	37	34	31	7.41
Czech Republic	6.5	10.4	16.5	23.1	23.8	24.5	0.54	0.62	0.77	0.92	0.85	0.82	30	29	25	25	28	32	3.75
Pakistan	1.2	2.8	7.3	12.0	19.5	23.6	0.10	0.17	0.34	0.48	0.70	0.79	55	49	44	42	37	33	19.12
Norway	6.7	9.7	14.3	18.3	21.9	23.4	0.55	0.58	0.67	0.73	0.78	0.78	28	31	34	34	32	34	3.51
Hong Kong	7.6	11.9	14.3	17.5	21.3	23.1	0.62	0.71	0.67	0.70	0.76	0.77	26	27	33	35	33	35	3.06
Singapore	6.0	10.4	14.5	18.8	20.7	21.6	0.49	0.62	0.68	0.75	0.74	0.72	32	30	32	30	35	36	3.63
Israel	12.0	14.3	16.0	18.6	20.1	21.3	0.99	0.86	0.75	0.74	0.72	0.71	21	22	27	31	36	37	1.77
Finland	9.6	12.6	15.1	18.5	19.5	20.9	0.79	0.75	0.71	0.74	0.70	0.70	23	24	30	33	38	38	2.18
Thailand	2.2	4.9	9.5	12.4	17.7	19.0	0.19	0.30	0.44	0.49	0.63	0.63	43	40	40	40	39	39	8.46
Greece	6.8	11.9	16.3	16.9	17.6	18.8	0.56	0.71	0.76	0.67	0.63	0.63	27	26	26	36	40	40	2.77

Notes. 1. For China we take data for Mainland China since Macao and Hong Kong are presented in Scopus as separate countries. 2. 40 countries with the highest number of publications in 2019 in Scopus are shown in this table.
Source: Derived from (Shashnov and Kotsemir 2018) and updated for 2019. Authors' calculations from data taken from Scopus database. Types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Further details are shown on Table 3.2, which, in addition, illustrates the share of South Africa in global scientific publication output. In the global ranking on the total number of publications, South Africa is among the top 30 countries. According tio the table, South Africa has moved from 36th place in 2000 to 28th in 2019. However, the growth of publications of South Africa is quite slow in comparison to fast growing countries from top-50 by number of publications in 2019. Countries like Portugal, Iran, Saudi Arabia, Malaysia and Indonesia had lower number of publications than South Africa in the year 2000, but in 2019, they outperformed South Africa by number of publications. Pakistan and Egypt that started with lower number of publications in 2000 came closer to South Africa by 2019.

On the other hand, Finland and Israel, that had in 2000 much higher number of publications than South Africa has lower number of publications than South Africa in 2019. Furthermore,

Austria and Denmark that have much higher number of publications than South Africa in 2000 can only slightly outperform South Africa by number of publications in 2019.

South Africa is the leader by number of Scopus-indexed publications among all African countries. In 2019 South Africa holds 28th position in global rankings with 26.4 ths publications. Egypt takes the second-place with number of publications comparable to South Africa and 31st place by number publications in 2019 (24.6 ths publications). Other African countries stay far behind South Africa and Egypt. In 2019, Nigeria holds 51st position in global rankings by number of Scopus-indexed publications (10.9 ths publications); Algeria – 54th position (8.1 ths publications); Tunisia – 57th position (7.8 ths publications); Ethiopia 66th position (4.2 ths publications) etc.

3.4. Citation analysis

Table 3.3 shows key citation indicators for South Africa, top-10 countries by number of publications in 2019, benchmark countries with very high citation indicators (Singapore, Hong Kong, Denmark, Switzerland, Netherlands) and in BRICS, EU-28, OECD, SADC countries and countries of Africa for 2000 – 2019.

Field-Weighted Citation Impact (FWCI) of South Africa shows that publications of South Africa since 2005 are cited more actively than the world average. With this, the FWCI level of South Africa is higher than in BRICS countries and African countries, which is comparable with the OECD, EU-28 and SADC countries level, and only lower that in some top-10 countries (UK, USA, Germany, Italy, France, Canada) by number of publications in 2019 and much lower than in benchmark countries with very high citation indicators.

In the period of 2000-2019, 39%-43% of all publications of South Africa are publications in Q1 journals. Share of publications in Q1 journals by CiteScore in all publications of South Africa is higher than in BRICS countries and African countries. This figure is comparable with SADC countries level, slightly lower than in OECD, EU-28 and much lower than in some top-10 countries by number of publications in 2019 (like US, UK, Germany, France, Canada) and in benchmark countries with very high citation indicators. Share of publications in top 1% Citation Percentiles in all publications of South Africa jumped from 0.54% in 2000 to 1.36% in 2010, and since 2010 was on the level of 1.36% - 1.50%.

By the value of this indicator South Africa is much better than African counties in total, and is slightly better than BRICS, OECD, EU-28 and SADC countries. However, by the share of publications in top 1% citation percentiles is far behind from benchmark countries with the highest values of citation indicators.

Table 3.3. Key citation indicators of South Africa in comparison to other countries and country groups in Scopus

Country or Country group	Field-Weighted Citation Impact, points (world average level is 1.00)						Share of publications in Q1 Journal Quartile by CiteScore in all publications of a country, %						Share of publications in Top 1% Citation Percentiles in all publications of a country, % (world average level is 1.00)					
	2000	2005	2010	2015	2018	2019	2000	2005	2010	2015	2018	2019	2000	2005	2010	2015	2018	2019
South Africa	**0.87**	**1.07**	**1.21**	**1.28**	**1.24**	**1.16**	**39.2**	**39.4**	**39.0**	**40.8**	**43.1**	**42.2**	**0.54**	**1.01**	**1.36**	**1.37**	**1.48**	**1.42**
Top-10 countries by number of publications in Scopus in 2019																		
China	0.48	0.55	0.67	0.93	1.05	1.06	24.3	19.9	21.8	37.3	42.8	45.1	0.21	0.35	0.54	1.16	1.67	1.86
United States	1.50	1.50	1.52	1.49	1.41	1.40	55.3	51.1	52.2	54.8	56.0	55.6	2.06	2.07	2.20	2.16	1.94	1.87
United Kingdom	1.39	1.49	1.55	1.61	1.56	1.56	56.5	53.1	52.5	56.7	60.1	60.7	1.59	1.96	2.21	2.38	2.23	2.23
India	0.58	0.69	0.75	0.76	0.85	0.81	32.8	35.1	27.7	25.4	24.3	24.5	0.31	0.52	0.56	0.61	0.71	0.83
Germany	1.23	1.33	1.42	1.43	1.34	1.35	48.0	45.3	46.9	50.4	51.5	51.9	1.16	1.47	1.87	1.97	1.78	1.87
Japan	0.90	0.90	0.92	0.93	0.93	0.94	41.1	38.4	37.7	38.7	40.6	40.4	0.58	0.70	0.80	0.98	0.98	1.15
Italy	1.14	1.28	1.37	1.46	1.43	1.41	50.2	47.4	46.2	46.8	48.7	47.6	0.91	1.31	1.57	1.66	1.70	1.72
Russian Federation	0.50	0.53	0.55	0.74	0.76	0.81	20.3	19.4	18.7	18.1	15.6	15.9	0.22	0.29	0.37	0.41	0.42	0.49
France	1.19	1.27	1.34	1.35	1.30	1.27	49.3	47.4	47.3	49.6	51.7	52.7	1.09	1.35	1.63	1.79	1.74	1.78
Canada	1.40	1.46	1.50	1.56	1.45	1.47	54.5	50.8	51.8	55.9	57.3	57.9	1.58	1.74	2.00	2.15	1.98	2.18
Some benchmark countries with high citation indicators (from top-50 countries by number of publications in Scopus in 2019)																		
Singapore	1.03	1.43	1.65	1.81	1.85	1.82	43.6	45.5	49.6	57.1	59.0	59.2	0.66	1.40	2.40	3.55	4.10	4.26
Hong Kong	1.17	1.43	1.51	1.80	1.82	1.79	50.7	49.1	49.8	58.4	62.7	63.7	0.91	1.56	1.92	3.06	3.64	3.53
Denmark	1.55	1.72	1.78	1.93	1.77	1.76	58.9	58.2	58.1	60.9	63.6	64.6	1.75	2.43	2.69	2.98	2.73	2.74
Switzerland	1.61	1.82	1.86	1.94	1.78	1.73	54.6	54.4	55.5	58.8	61.9	61.8	2.06	2.55	3.05	3.43	3.25	2.99
Netherlands	1.55	1.67	1.81	1.84	1.73	1.72	59.8	56.7	58.3	62.9	63.8	64.4	1.74	2.34	2.83	2.97	2.68	2.69
Groups of countries																		
BRICS	0.55	0.60	0.69	0.86	0.95	0.96	27.0	23.7	23.3	32.7	35.9	37.6	0.27	0.39	0.52	0.91	1.23	1.39
Africa	0.72	0.81	0.87	0.94	1.00	1.00	38.0	35.7	31.3	32.5	34.6	34.3	0.32	0.54	0.71	0.83	0.87	0.97
OECD	1.20	1.22	1.23	1.20	1.15	1.16	49.2	45.3	44.7	46.9	48.8	49.0	1.26	1.31	1.36	1.31	1.24	1.25
EU28	1.15	1.20	1.23	1.22	1.18	1.19	48.7	45.2	43.9	46.3	48.3	48.6	1.05	1.21	1.31	1.32	1.24	1.27
SADC*	0.86	1.06	1.21	1.24	1.19	1.14	40.4	40.3	40.3	42.0	43.9	43.4	0.47	0.95	1.27	1.32	1.32	1.28

Notes. For China we take data for Mainland China. * SADC is Southern African Development Community

Source: Authors' calculations from Scopus SciVal "Benchmarking" Toolbox. Types of publications include articles, reviews, and conference papers. Scopus data last updated in SciVal as of 13 January 2021.

3.5. Thematic structure of publications

Table 3.4 shows the positions of South Africa in global science by Scopus subject areas in 2019. According to the table, South Africa lags behind other countries in global ranking on number of publications in Scopus. The country is placed usually below 20th in 27 Scopus subject areas. Among the "strongest" subject areas for South Africa in Scopus in 2019 are: "Social sciences" (15th and 6.9% to the global leader); "Arts and humanities" (15th and 5.3%); "Business, Management and Accounting" (17th and 10.2%); "Economics, Econometrics and Finance" (19th, 6.5%), "Agricultural and Biological Sciences" (20th position and 7.4% of the global leader). In "Agricultural and Biological" and "Social Science" also take quite high share in the total number of publications of South Africa in Scopus in 2019. On the other hand South Africa stand behind top-40 countries in 2019 in Scopus subject areas like «Neuroscience" (41st place); "Engineering" (42nd place); Mathematics (43rd place), "Computer Science" (44th place) and finally "Dentistry (50th place).

Table 3.4 Positions of South Africa in global science by Scopus subject areas in 2019

Subject Area	Number of South Africa publications in subject area in 2019	Share of subject area in all South Africa publications in 2019	Position of South Africa in the global ranking of countries by number of publications in subject area in 2019	% of South Africa to global leader by number of publications in 2019	Global leader by number of publications
Agricultural and Biological Sciences	3 668	13.9%	20	7.4%	China (since 2019)
Arts and Humanities	1 654	6.3%	15	6.3%	USA
Biochemistry, Genetics and Molecular Biology	2 217	8.4%	34	2.6%	China (since 2019)
Business, Management and Accounting	1 705	6.5%	17	10.2%	USA
Chemical Engineering	972	3.7%	34	1.7%	China (since 2009)
Chemistry	1 601	6.1%	35	1.7%	China (since 2007)
Computer Science	2 608	9.9%	44	2.1%	China (since 2006)
Decision Sciences	644	2.4%	27	4.0%	China (since 2017)
Dentistry	51	0.2%	50	1.8%	USA
Earth and Planetary Sciences	1 925	7.3%	22	4.2%	China (since 2015)
Economics, Econometrics and Finance	774	2.9%	19	6.5%	USA
Energy	1 130	4.3%	36	2.1%	China (since 2005)
Engineering	3 562	13.5%	42	1.6%	China (since 2007)
Environmental Science	2 519	9.5%	25	4.1%	China (since 2016)
Health Professions	424	1.6%	26	3.8%	USA
Immunology and Microbiology	997	3.8%	23	4.8%	USA
Materials Science	1 731	6.6%	39	1.3%	China (since 2007)
Mathematics	1 478	5.6%	43	2.1%	China (since 2012)
Medicine	5 641	21.4%	27	3.0%	USA
Multidisciplinary	658	2.5%	27	4.3%	USA
Neuroscience	285	1.1%	41	1.1%	USA
Nursing	455	1.7%	26	3.0%	USA
Pharmacology, Toxicology and Pharmaceutics	691	2.6%	33	2.9%	China (since 2018)
Physics and Astronomy	2 516	9.5%	38	2.2%	China (since 2013)
Psychology	826	3.1%	23	2.9%	USA
Social Sciences	4 942	18.7%	15	6.9%	USA
Veterinary	264	1.0%	26	5.8%	USA
Total	**26 379**		**28**	**3.9%**	**China (since 2019)**

Source: Authors' calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Besides the number of publications, it is also important to understand the key areas of competence in scientific work. These are demonstrated by the thematic structure of publications of South Africa in Scopus (Table 3.5). In 2005-2009 and 2015-2019 2.25% of Scopus-indexed publications of South Africa was concentrated in "Medicine". Among the other important areas in the thematic structure of publications of South Africa are: "Social Sciences", "Agricultural and Biological Sciences", and "Engineering".

Table 3.5. Key indicators of thematic structure of publications of South Africa in Scopus in 2005-2009 and 2015-2019

Subject area	Relative comparative advantage (RCA) index value in South Africa		Share of subject area in the total number of publications of country			
			South Africa		World	
	2005-2009	2015-2019	2005-2009	2015-2019	2005-2009	2015-2019
Agricultural and Biological Sciences	2.72	1.83	19.1%	14.5%	7.0%	8.0%
Arts and Humanities	1.94	1.74	6.6%	6.8%	3.4%	3.9%
Biochemistry, Genetics and Molecular Biology	0.85	0.78	9.7%	8.8%	11.4%	11.2%
Business, Management and Accounting	1.09	2.08	2.7%	5.6%	2.5%	2.7%
Chemical Engineering	0.68	0.64	3.0%	3.3%	4.4%	5.2%
Chemistry	0.73	0.70	6.7%	6.4%	9.2%	9.1%
Computer Science	0.55	0.62	6.6%	8.7%	12.0%	14.1%
Decision Sciences	1.12	1.41	1.1%	2.4%	1.0%	1.7%
Dentistry	0.60	0.32	0.3%	0.2%	0.5%	0.5%
Earth and Planetary Sciences	1.93	1.47	9.1%	7.4%	4.7%	5.0%
Economics, Econometrics and Finance	1.44	1.60	2.0%	2.8%	1.4%	1.7%
Energy	0.80	0.78	2.2%	3.7%	2.8%	4.8%
Engineering	0.56	0.56	12.5%	12.4%	22.3%	22.2%
Environmental Science	1.81	1.34	8.3%	8.5%	4.6%	6.3%
Health Professions	0.88	1.32	0.9%	1.6%	1.0%	1.2%
Immunology and Microbiology	2.02	1.45	5.7%	3.9%	2.8%	2.7%
Materials Science	0.54	0.58	6.0%	6.7%	11.2%	11.5%
Mathematics	0.75	0.68	5.4%	5.4%	7.2%	7.9%
Medicine	0.86	0.95	21.5%	21.6%	24.9%	22.8%
Multidisciplinary	0.74	1.19	0.7%	2.6%	0.9%	2.2%
Neuroscience	0.44	0.50	1.1%	1.2%	2.5%	2.4%
Nursing	0.87	1.02	1.5%	1.6%	1.7%	1.6%
Pharmacology, Toxicology and Pharmaceutics	0.74	0.85	2.3%	2.7%	3.1%	3.2%
Physics and Astronomy	0.63	0.79	8.8%	10.1%	14.1%	12.7%
Psychology	1.34	1.23	2.6%	2.8%	2.0%	2.3%
Social Sciences	1.95	2.01	13.8%	17.6%	7.1%	8.8%
Veterinary	1.94	1.45	1.8%	1.1%	0.9%	0.8%

Source: Authors' calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

The key areas of scientific specialisation of South Africa in Scopus in 2005 – 2009 and 2015 – 2019 are: "Social Sciences", "Agricultural and Biological Sciences" and "Arts and Humanities". Values of Revealed comparative advantages (RCA) index for these subject areas. Was higher than 1.70 in 2005-2009 and 2015-2019.

Also for some areas of Scientific specialisation, we can see the fast increase of RCA index value in 2015-2019 in comparison to 2015-2019: "Business, Management and Accounting" from 1.09 to 2.08, for "Decision Sciences" from 1.12 to 1.41, for "Economics, Econometrics and Finance" from 1.44 to 1.60. "Health Professions", "Multidisciplinary" and "Nursing" became the areas of scientific specialisation of South Africa in 2015.-2019. Other areas of specialisation of South Africa in 2005-2009 and 2015-2019 like ''Earth and Planetary sciences", "Environmental science", "Immunology and Microbiology", "Psychology" and "Veterinary" show decrease of RCA value in 2015-2019 to 2005-2009.

"Dentistry" and "Neuroscience" show the lowest values of RCA index in the structure of publications of South Africa in Scopus in 2005-2009 and 2015-2019. In 2015-2019 subject areas

like “Chemical Engineering”, “Computer Science”, “Engineering”, “Material Science”, Mathematics” have quite low level of RCA index – 0.58-0.70.

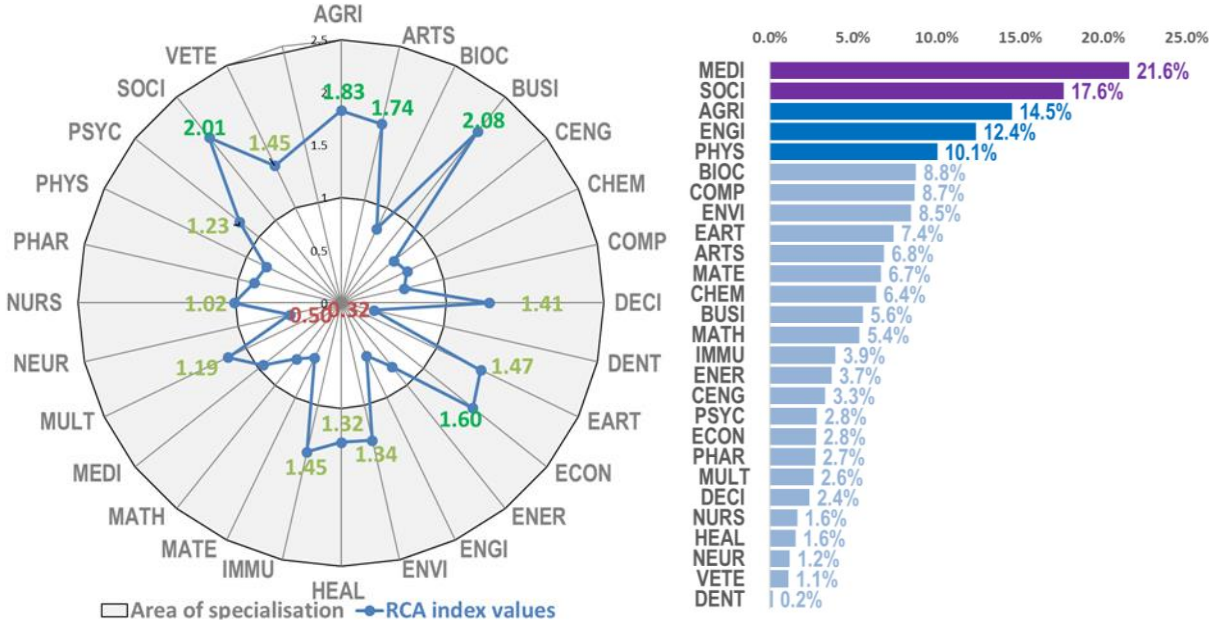

Figure 3.3. Specialization areas of South Africa Subject structure of publications of South Africa by Scopus subject areas for 2015 - 2019

27 Scopus subject areas are abbreviated as follows: AGRI – Agricultural and Biological Sciences; ARTS – Arts and Humanities; BIOC – Biochemistry, Genetics and Molecular Biology; BUSI – Business, Management and Accounting; CENG – Chemical Engineering; CHEM – Chemistry; COMP – Computer Science; DECI – Decision Sciences; DENT – Dentistry; EART – Earth and Planetary Sciences; ECON – Economics, Econometrics and Finance; ENER – Energy; ENGI – Engineering; ENVI – Environmental Science; HEAL – Health Professions; IMMU – Immunology and Microbiology; MATE – Materials Science; MATH – Mathematics; MEDI – Medicine; MULT – Multidisciplinary; NEUR – Neuroscience; NURS – Nursing; PHAR – Pharmacology, Toxicology and Pharmaceutics; PHYS – Physics and Astronomy; PSYC – Psychology; SOCI – Social Sciences; VETE – Veterinary.
Source: Authors’ calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Figure 3.3 presents the specialization areas of South Africa and its thematic structure in 2015-2019 by Scopus subject areas in a more illustrative way. Figure illustrates that South Africa has very high level of RCA index in “BUSI – Business, Management and Accounting” (2.08), “SOCI - Social Sciences” (2.01), “AGRI - Agricultural and Biological Sciences” (1.83), “ARTS - Arts and Humanities” (RCA: 1.74), “ECON - Economics, Econometrics and Finance” (1.60);;; and. Other areas of scientific specialization is also observed in “EART – Earth and Planetary Sciences”, “IMMU – Immunology and Microbiology”, “VETE – Veterinary”, “DECI – Decision Sciences”, “ENVI – Environmental Science”, “HEAL – Health Professions”, “PSYC – Psychology”, “MULT – Multidisciplinary”, “NURS – Nursing” ($1.0 < RCA < 1.47$). Low specialization is observed in some of the key areas like “MATH – Mathematics”, “CENG – Chemical Engineering”, “COMP – Computer Science”, “MATE – Materials Science”, “ENGI – Engineering”, “NEUR – Neuroscience”, “DENT – Dentistry” ($RCA < 0.75$). Considering the science and technology priority domains and priorities for South Africa, particularly Engineering and Computer Sciences areas need immediate attention for the development of the scientific

capacity. Key areas of research in South Africa in 2015-2019 are “Medicine” and “Social sciences” and to a lesser “Agricultural and biological sciences”, “Engineering” and “Physics and Astronomy”.

3.6. International collaboration

Another important aspect of scientific work is ‘international collaboration’, which represents joint research and knowledge exchange between countries. Figure 3.4 shows dynamics of South Africa’s research collaboration measured in join international publications. In 2004, the share of internationally collaborated publications in the total number of publications jumped from 29.6% to 38.4% and further by 2019 this indicator gradually increased to 52.0%.

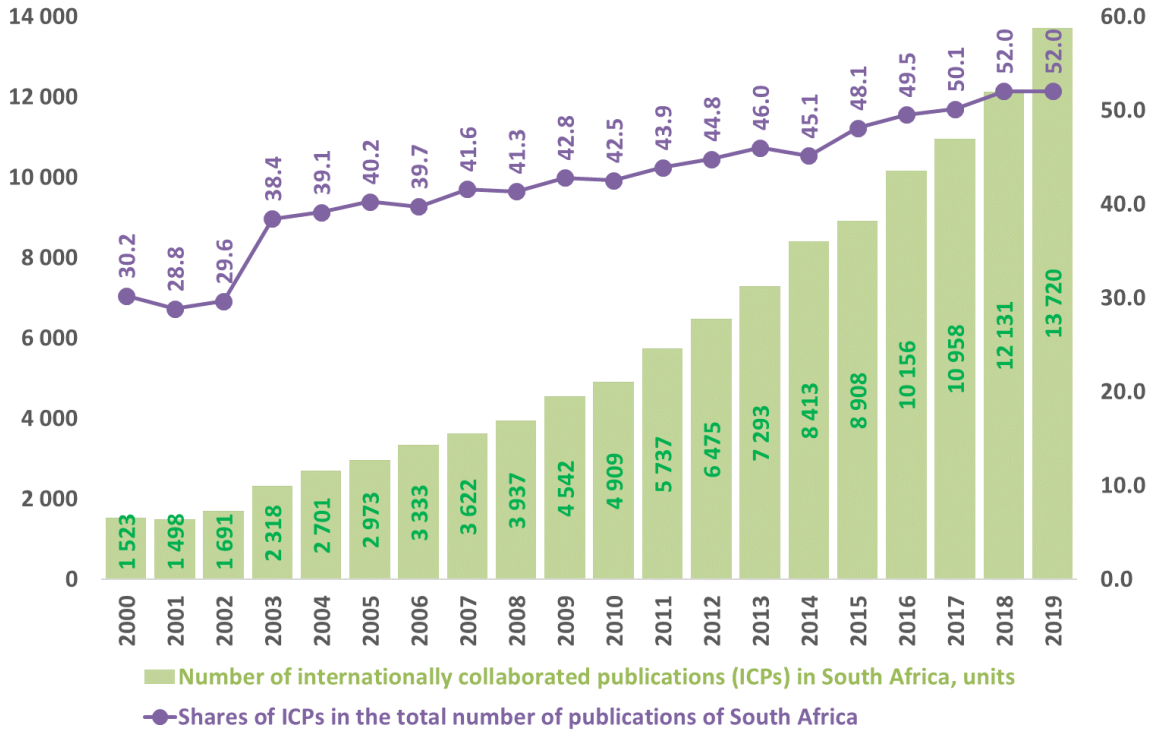

Figure 3.3. Key indicators of international research collaboration of South Africa in Scopus in 2000 – 2019.

Source: Authors’ calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Table 3.6 shows the key scientific partners of South Africa in research collaboration in Scopus are the United States and the United Kingdom during 2000 – 2019. Australia and European countries like Germany, France, and the Netherlands are among the top scientific partners of South Africa. Among BRICS countries India and China are among top 10 partner countries in Scopus in 2019. We should note the burst of joint publications of South Africa and Kenya – from 12 in 2000 to 1410 in 2019 so Kenya in 2019 became 5th most important partner of South Africa in Scopus. In this aspect (i.e. very fast growth of joint publications with South Africa for 2000-2019) we can

see countries like Portugal, Ghana, Iran, Uganda, Romania, Thailand, Pakistan, and Tanzania among the others.

Table 3.6. Key scientific partners of South Africa in international research collaboration in Scopus in 2000, 2005, 2010, 2015 and 2019

Country	Number of joint publications with a country					Growth of joint papers 2019 to 2000, times	Share of a country in all internationally collaborated publications (ICPs) of South Africa				
	2000	2005	2010	2015	2019		2000	2005	2010	2015	2019
All ICPs of South Africa	**1 523**	**2 973**	**4 909**	**8 908**	**13 720**	**9.01**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
1. United States	492	994	1 554	2 937	3 943	8.01	32.30%	33.43%	31.66%	32.97%	28.74%
2. United Kingdom	369	636	1 121	2 000	3 054	8.28	24.23%	21.39%	22.84%	22.45%	22.26%
3. Australia	152	286	511	1 104	1 661	10.93	9.98%	9.62%	10.41%	12.39%	12.11%
4. Germany	187	340	558	1 179	1 591	8.51	12.28%	11.44%	11.37%	13.24%	11.60%
5. Nigeria	12	48	175	390	1 410	117.50	0.79%	1.61%	3.56%	4.38%	10.28%
6. France	113	235	463	987	1 235	10.93	7.42%	7.90%	9.43%	11.08%	9.00%
7. China	30	73	183	543	1 177	39.23	1.97%	2.46%	3.73%	6.10%	8.58%
8. Netherlands	83	174	341	847	1 138	13.71	5.45%	5.85%	6.95%	9.51%	8.29%
9. India	33	74	210	723	1 065	32.27	2.17%	2.49%	4.28%	8.12%	7.76%
10. Canada	102	203	363	839	1 038	10.18	6.70%	6.83%	7.39%	9.42%	7.57%
11. Italy	49	101	258	594	932	19.02	3.22%	3.40%	5.26%	6.67%	6.79%
12. Sweden	38	80	241	588	865	22.76	2.50%	2.69%	4.91%	6.60%	6.30%
13. Switzerland	55	105	241	614	844	15.35	3.61%	3.53%	4.91%	6.89%	6.15%
14. Spain	31	82	216	597	835	26.94	2.04%	2.76%	4.40%	6.70%	6.09%
15. Brazil	22	53	135	441	667	30.32	1.44%	1.78%	2.75%	4.95%	4.86%
16. Belgium	56	157	214	428	654	11.68	3.68%	5.28%	4.36%	4.80%	4.77%
17. Japan	48	65	166	391	558	11.63	3.15%	2.19%	3.38%	4.39%	4.07%
18. Russia	33	37	96	361	496	15.03	2.17%	1.24%	1.96%	4.05%	3.62%
19. Norway	19	57	161	405	472	24.84	1.25%	1.92%	3.28%	4.55%	3.44%
20. Poland	26	56	108	326	468	18.00	1.71%	1.88%	2.20%	3.66%	3.41%
21. Denmark	26	61	158	391	423	16.27	1.71%	2.05%	3.22%	4.39%	3.08%
22. Kenya	20	48	110	256	421	21.05	1.31%	1.61%	2.24%	2.87%	3.07%
23. Portugal	4	24	68	286	406	101.50	0.26%	0.81%	1.39%	3.21%	2.96%
24. Turkey	10	19	60	253	377	37.70	0.66%	0.64%	1.22%	2.84%	2.75%
25. Austria	28	56	116	302	376	13.43	1.84%	1.88%	2.36%	3.39%	2.74%
26. Zimbabwe	28	36	72	190	356	12.71	1.84%	1.21%	1.47%	2.13%	2.59%
27. Finland	16	24	67	223	354	22.13	1.05%	0.81%	1.36%	2.50%	2.58%
28. Saudi Arabia	8	11	44	185	352	44.00	0.53%	0.37%	0.90%	2.08%	2.57%
29. Czech Republic	8	40	75	263	348	43.50	0.53%	1.35%	1.53%	2.95%	2.54%
30. Chile	13	15	69	267	347	26.69	0.85%	0.50%	1.41%	3.00%	2.53%
31. Ghana	1	7	41	138	329	329.00	0.07%	0.24%	0.84%	1.55%	2.40%
32. Iran	2	13	34	150	321	160.50	0.13%	0.44%	0.69%	1.68%	2.34%
33. New Zealand	48	62	103	225	306	6.38	3.15%	2.09%	2.10%	2.53%	2.23%
34. Greece	14	16	44	247	304	21.71	0.92%	0.54%	0.90%	2.77%	2.22%
35. Argentina	9	39	83	225	297	33.00	0.59%	1.31%	1.69%	2.53%	2.16%
36. Israel	33	42	77	232	290	8.79	2.17%	1.41%	1.57%	2.60%	2.11%
37. South Korea	6	14	46	143	269	44.83	0.39%	0.47%	0.94%	1.61%	1.96%
38. Mexico	16	32	86	159	260	16.25	1.05%	1.08%	1.75%	1.78%	1.90%
38. Romania	3	7	43	220	260	86.67	0.20%	0.24%	0.88%	2.47%	1.90%
40. Thailand	3	24	48	167	252	84.00	0.20%	0.81%	0.98%	1.87%	1.84%
40. Uganda	1	21	62	154	252	252.00	0.07%	0.71%	1.26%	1.73%	1.84%
42. Taiwan	7	16	35	183	249	35.57	0.46%	0.54%	0.71%	2.05%	1.81%
43. Pakistan	3	7	34	119	239	79.67	0.20%	0.24%	0.69%	1.34%	1.74%
44. Hong Kong	11	16	29	172	233	21.18	0.72%	0.54%	0.59%	1.93%	1.70%
45. Botswana	4	33	41	91	226	56.50	0.26%	1.11%	0.84%	1.02%	1.65%
46. Colombia	3	8	33	191	216	72.00	0.20%	0.27%	0.67%	2.14%	1.57%
47. Hungary	17	36	70	206	210	12.35	1.12%	1.21%	1.43%	2.31%	1.53%
48. Serbia	0	4	14	163	204	…	0.00%	0.13%	0.29%	1.83%	1.49%
49. Ethiopia	9	37	35	92	203	22.56	0.59%	1.24%	0.71%	1.03%	1.48%
49. Tanzania	1	19	48	123	203	203.00	0.07%	0.64%	0.98%	1.38%	1.48%

Note. 50 most important partners of South Africa in research collaboration in Scopus in 2019 are shown in this table.

Source: Authors' calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

Table 3.7 presents the thematic structure of internationally collaborated publications of South Africa in years 2005-2009 and 2015-2019, 2010 and 2017 by Scopus subject area. It is seen that subject areas like Business, Management and Accounting; Health Professions; Decision Sciences; Nursing; and Arts and Humanities are gaining momentum in terms of the growth of their share in total number of publications.

Table 3.7. Thematic structure of internationally collaborated publications (ICPs) of South Africa in years 2000, 2010 and 2017 by Scopus subject area

Subject area	Number of ICPs of South Africa in subject area, units		Share of Subject area in total number of ICPs of South Africa		Share of ICPs in the total number of publications in subject area	
	2005-2009	2015-2019	2005-2009	2015-2019	2005-2009	2015-2019
Agricultural and Biological Sciences	4 231	9 676	23.0%	17.3%	49.8%	60.2%
Arts and Humanities	520	2 028	2.8%	3.6%	17.6%	26.8%
Biochemistry, Genetics and Molecular Biology	2 272	6 155	12.3%	11.0%	52.7%	63.5%
Business, Management and Accounting	286	1 836	1.6%	3.3%	23.3%	29.8%
Chemical Engineering	514	1 838	2.8%	3.3%	38.4%	49.9%
Chemistry	1 247	3 779	6.8%	6.8%	41.6%	53.7%
Computer Science	893	3 262	4.9%	5.8%	30.2%	33.9%
Decision Sciences	153	738	0.8%	1.3%	30.7%	28.0%
Dentistry	51	80	0.3%	0.1%	35.9%	41.2%
Earth and Planetary Sciences	2 145	5 320	11.7%	9.5%	52.9%	64.6%
Economics, Econometrics and Finance	247	1 263	1.3%	2.3%	27.6%	41.2%
Energy	317	1 783	1.7%	3.2%	31.9%	43.5%
Engineering	1 712	5 894	9.3%	10.5%	30.8%	43.1%
Environmental Science	1 542	5 314	8.4%	9.5%	41.7%	56.7%
Health Professions	132	897	0.7%	1.6%	32.5%	52.2%
Immunology and Microbiology	1 422	3 000	7.7%	5.4%	56.3%	68.7%
Materials Science	1 070	3 903	5.8%	7.0%	39.8%	53.0%
Mathematics	1 097	3 240	6.0%	5.8%	45.3%	54.4%
Medicine	4 540	14 569	24.7%	26.1%	47.2%	61.1%
Multidisciplinary	241	2 201	1.3%	3.9%	79.0%	76.0%
Neuroscience	272	932	1.5%	1.7%	56.7%	69.7%
Nursing	270	945	1.5%	1.7%	41.4%	51.9%
Pharmacology, Toxicology and Pharmaceutics	468	1 597	2.5%	2.9%	45.8%	53.0%
Physics and Astronomy	2 246	7 687	12.2%	13.8%	57.0%	69.1%
Psychology	431	1 614	2.3%	2.9%	36.7%	51.5%
Social Sciences	1 558	6 402	8.5%	11.5%	25.3%	32.8%
Veterinary	397	771	2.2%	1.4%	50.5%	62.4%
Total	**18 407**	**55 873**	**100%**	**100%**	**41.3%**	**50.5%**

Source: Authors' calculations from data taken from the Scopus database. The types of publications include articles, reviews, and conference papers. Data is current as of May 2020.

3.7. Data on publication activity of South Africa by S&T Domains in Microsoft Academic Graph database

Tables 3.8 – 3.15 provide the key results of bibliometric analysis of Microsoft Academic Graph (MAG)-indexed publications of South Africa in four domains of S&T development of a country (Health Innovation, Circular Economy, Education, and High-techn Industry).

Table 3.8 shows the publication activity of South Africa in the Health Innovation domain. The country started producing more scientific publications particularly from 2015 onwards, contributing to 1% of the total publications produced in the field. The country's performance has increased in global rankings from the 26th in 2000 to 20th in 2019.

Table 3.8. Key indicators of publication Activity of South Africa and leading countries in "Health Innovation" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Number of publication of a country in "Health Innovation" domain, thousands units								
World	**397.8**	**677.9**	**1 074.1**	**1 380.6**	**1 290.9**	**1 184.2**	**1 110.2**	**797.9**
USA	123.2	191.2	264.7	342.8	333.6	307.6	281.3	226.9
China	11.0	52.9	119.5	119.6	103.7	107.0	109.9	97.1
UK	35.2	52.1	76.8	102.6	102.6	100.4	93.6	72.0
Germany	20.2	31.1	45.4	55.8	55.8	53.3	49.8	38.9
Australia	12.8	23.0	37.1	50.0	49.0	48.1	44.4	35.3
Canada	13.8	24.3	35.8	47.3	47.2	45.4	41.8	33.1
India	4.2	8.9	21.6	46.3	51.1	47.0	44.1	31.8
Italy	11.0	18.5	28.0	41.1	41.0	40.1	36.7	29.0
France	12.5	19.1	29.6	37.3	37.6	36.6	33.5	25.8
Japan	22.0	30.2	34.4	38.6	38.2	36.1	33.4	24.9
…	…	…	…	…	…	…	…	…
Belgium	4.0	6.5	10.8	14.6	14.1	13.4	12.9	9.9
Denmark	2.9	4.9	7.7	12.1	12.6	12.2	11.4	8.9
South Africa	2.1	4.1	7.7	12.4	12.6	12.6	11.9	8.9
Russia	3.1	4.1	5.9	11.5	12.6	12.6	13.4	8.7
Turkey	1.8	5.3	8.1	14.6	14.6	12.5	11.1	8.4
Share of country in the global number of publications in "Health Innovation" domain, %								
USA	30.97	28.20	24.64	24.83	25.84	25.97	25.34	28.44
China	2.77	7.81	11.13	8.66	8.03	9.04	9.90	12.17
UK	8.84	7.69	7.15	7.43	7.94	8.47	8.43	9.02
Germany	5.09	4.58	4.22	4.04	4.33	4.50	4.48	4.87
Australia	3.21	3.40	3.46	3.62	3.80	4.06	4.00	4.42
Canada	3.48	3.59	3.33	3.43	3.65	3.83	3.76	4.15
India	1.07	1.31	2.01	3.35	3.96	3.97	3.98	3.99
Italy	2.76	2.73	2.61	2.97	3.17	3.39	3.30	3.63
France	3.15	2.82	2.76	2.70	2.92	3.09	3.02	3.23
Japan	5.52	4.45	3.21	2.79	2.96	3.05	3.01	3.12
…	…	…	…	…	…	…	…	…
Belgium	0.99	0.96	1.00	1.06	1.09	1.14	1.16	1.24
Denmark	0.74	0.72	0.72	0.87	0.97	1.03	1.02	1.12
South Africa	0.52	0.61	0.71	0.90	0.97	1.06	1.07	1.12
Russia	0.78	0.61	0.55	0.83	0.97	1.06	1.20	1.09
Turkey	0.46	0.78	0.75	1.06	1.13	1.06	1.00	1.05
Position of a country in the global ranking by number of publications in "Health Innovation" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	8	2	2	2	2	2	2	2
UK	2	3	3	3	3	3	3	3
Germany	4	4	4	4	4	4	4	4
Australia	6	7	5	5	6	5	5	5
Canada	5	6	6	6	7	7	7	6
India	16	16	11	7	5	6	6	7
Italy	9	9	9	8	8	8	8	8
France	7	8	8	10	10	9	9	9
Japan	3	5	7	9	9	10	10	10
Belgium	17	17	17	18	19	18	19	18
Denmark	20	19	20	22	23	22	21	19
South Africa	26	24	21	21	21	19	20	20
Russia	19	25	26	23	22	20	18	21
Turkey	29	18	19	19	18	21	23	22

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

Regarding key citation indicators, South Africa's ranking in impact has been increasing. In 2019, South African publications received twice more citations. With this the country occupies the 20th position in the world. However, the impact of publications from South Africa has been stable and didn't show much progress since then.

Table 3.9. Key citation indicators of South Africa and leading countries on "Health Innovation" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Share of a country in the global number of citation received on publications in "Health Innovation" domain, %								
USA	55.99	54.15	51.20	47.38	46.86	44.51	43.95	42.40
China	1.96	3.81	7.14	12.05	13.13	15.14	16.99	17.75
UK	14.84	15.15	15.21	15.78	16.06	16.86	15.20	15.48
Germany	7.60	8.89	9.24	9.68	9.38	9.58	9.18	9.07
Australia	5.40	5.61	6.68	7.86	8.29	7.98	8.03	7.70
Canada	6.81	7.47	8.12	8.03	7.85	8.39	8.24	7.45
Italy	3.47	4.57	5.24	6.01	6.05	6.66	6.54	6.46
France	5.13	5.44	5.99	6.22	6.61	6.55	6.33	6.37
Netherlands	3.76	4.52	5.34	5.24	5.30	5.65	5.22	4.92
Spain	2.05	2.88	3.55	4.55	4.27	4.80	4.75	4.55
…	…	…	…	…	…	…	…	…
Brazil	0.94	1.45	2.05	2.69	2.64	2.87	2.85	2.51
Denmark	1.41	1.92	1.88	2.59	2.37	2.65	2.61	2.39
South Africa	0.84	1.26	1.56	2.05	1.73	2.24	2.08	1.74
Austria	1.00	1.45	1.58	1.85	1.61	1.75	1.57	1.69
Israel	1.19	1.27	1.20	1.59	1.45	1.53	1.52	1.59
Position of a country in the global ranking by number of citations received on publications in "Health Innovation" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	13	11	5	3	3	3	2	2
UK	2	2	2	2	2	2	3	3
Germany	3	3	3	4	4	4	4	4
Australia	5	5	6	6	5	6	6	5
Canada	4	4	4	5	6	5	5	6
Italy	9	8	9	8	8	7	7	7
France	6	6	7	7	7	8	8	8
Netherlands	8	9	8	9	9	9	9	9
Spain	12	13	12	10	10	10	10	10
…	…	…	…	…	…	…	…	…
Brazil	22	17	17	17	17	16	16	18
Denmark	15	15	18	18	18	17	18	19
South Africa	23	23	20	19	19	19	20	20
Austria	20	18	19	20	21	23	25	21
Israel	16	22	23	25	24	27	27	22
Citation impact of country in "Health Innovation" domain relative to world, points								
USA	1.81	1.92	2.08	1.91	1.81	1.71	1.73	1.49
China	0.71	0.49	0.64	1.39	1.63	1.67	1.72	1.46
UK	1.68	1.97	2.13	2.12	2.02	1.99	1.80	1.72
Germany	1.49	1.94	2.19	2.40	2.17	2.13	2.05	1.86
Australia	1.68	1.65	1.93	2.17	2.18	1.97	2.01	1.74
Canada	1.96	2.08	2.44	2.34	2.15	2.19	2.19	1.79
Italy	1.26	1.67	2.01	2.02	1.91	1.96	1.98	1.78
France	1.63	1.93	2.17	2.30	2.27	2.12	2.10	1.97
Netherlands	1.81	2.32	2.78	2.70	2.52	2.47	2.21	1.97
Spain	1.28	1.63	1.83	2.17	1.88	1.96	1.90	1.63
…	…	…	…	…	…	…	…	…
Brazil	0.84	1.06	1.10	1.19	1.12	1.22	1.16	0.97
Denmark	1.91	2.68	2.62	2.96	2.44	2.58	2.55	2.13
South Africa	1.62	2.07	2.19	2.28	1.78	2.10	1.95	1.56
Austria	1.50	2.19	2.58	2.89	2.43	2.52	2.31	2.20
Israel	1.38	1.84	2.21	3.06	2.50	2.58	2.67	2.34

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph and Crossref database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

Table 3.10 shows the publication activity of South Africa in the Circular Economy domain. The country's quantity of publications has increased substantially since 2015 in this domain. With this the South Africa produces more than 2% of the scientific outout in the World, which shows the increasing emphasis on the topic in scientific work. The country's position in global rankings is 16th.

Table 3.10. Key indicators of publication Activity of South Africa and leading countries in "Circular economy" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Number of publication of a country in "Circular Economy" domain, thousands units								
World	**125.7**	**227.7**	**448.7**	**634.8**	**598.8**	**575.8**	**563.3**	**410.8**
USA	31.0	52.2	85.2	116.2	114.9	110.7	104.8	84.8
China	2.8	16.5	49.6	56.9	51.3	58.1	64.8	63.2
UK	9.0	14.4	25.1	37.2	38.3	39.5	37.9	30.3
India	1.8	3.7	11.2	25.7	28.8	28.5	28.4	22.1
Australia	4.0	7.9	15.9	22.8	22.4	22.5	21.3	17.9
Germany	4.4	7.8	15.1	22.3	23.4	23.1	22.5	17.6
Canada	3.7	6.7	11.9	17.4	17.9	17.8	17.0	14.0
Italy	2.1	4.0	8.3	15.4	15.5	16.6	15.9	12.8
Spain	1.7	3.8	8.1	13.2	13.7	14.4	14.2	11.9
France	2.8	5.3	10.3	15.2	15.7	15.5	14.6	11.3
…	…	…	…	…	…	…	…	…
Iran	0.1	0.8	3.3	8.2	8.6	8.7	9.0	8.6
Netherlands	2.2	4.3	7.4	10.4	10.9	11.0	10.7	8.4
South Africa	1.4	2.9	5.9	9.8	10.7	10.9	10.4	8.3
Sweden	1.5	2.8	5.3	8.4	7.9	7.7	7.7	6.0
Switzerland	1.4	2.6	5.3	7.7	7.8	7.9	7.2	5.5
Share of country in the global number of publications in "Circular Economy" domain, %								
USA	24.65	22.91	19.00	18.30	19.18	19.23	18.60	20.65
China	2.24	7.26	11.05	8.96	8.56	10.08	11.50	15.39
UK	7.20	6.33	5.58	5.86	6.40	6.85	6.72	7.39
India	1.47	1.62	2.49	4.04	4.80	4.95	5.05	5.37
Australia	3.19	3.49	3.55	3.60	3.74	3.91	3.79	4.36
Germany	3.51	3.44	3.37	3.52	3.90	4.02	3.99	4.27
Canada	2.98	2.95	2.66	2.74	2.99	3.08	3.02	3.40
Italy	1.68	1.78	1.84	2.43	2.60	2.88	2.82	3.10
Spain	1.34	1.65	1.81	2.07	2.28	2.49	2.51	2.90
France	2.26	2.31	2.30	2.39	2.62	2.70	2.60	2.75
…	…	…	…	…	…	…	…	…
Iran	0.10	0.36	0.75	1.29	1.44	1.51	1.59	2.08
Netherlands	1.77	1.87	1.66	1.64	1.82	1.92	1.90	2.04
South Africa	1.13	1.25	1.32	1.54	1.78	1.89	1.84	2.01
Sweden	1.17	1.24	1.17	1.32	1.31	1.33	1.38	1.45
Switzerland	1.13	1.16	1.18	1.21	1.31	1.38	1.27	1.35
Position of a country in the global ranking by number of publications in "Circular Economy" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	8	2	2	2	2	2	2	2
UK	2	3	3	3	3	3	3	3
India	11	12	7	4	4	4	4	4
Australia	5	4	4	5	6	6	6	5
Germany	4	6	5	6	5	5	5	6
Canada	6	7	6	7	7	7	7	7
Italy	10	10	10	8	9	8	8	8
Spain	12	11	11	11	11	10	10	9
France	7	8	9	9	8	9	9	10
…	…	…	…	…	…	…	…	…
Iran	46	34	20	18	17	17	16	14
Netherlands	9	9	13	14	14	13	13	15
South Africa	15	15	15	15	15	14	14	16
Sweden	13	16	17	17	18	19	19	17
Switzerland	14	17	16	19	19	18	21	18

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

Table 3.11 shows the key citation indicators of South Africa. Over the past few years the country has received increased number of citations, but the year 2019 saw a decline. With this, the global ranking of the country is the 19th. The impact of the scientific work has remained pretty much stable since the year 2000.

Table 3.11. Key citation indicators of South Africa and leading countries on "Circular Economy" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Share of a country in the global number of citation received on publications in "Circular Economy" domain, %								
USA	50.68	46.88	42.29	37.93	36.50	34.66	32.34	29.48
China	1.64	4.09	10.01	18.65	20.59	23.42	26.49	28.72
UK	13.66	15.45	13.19	13.69	13.39	13.22	12.09	11.47
Australia	6.74	6.18	7.49	8.33	7.96	8.14	7.73	8.19
Germany	6.24	7.43	7.79	8.32	7.87	7.81	7.45	6.68
Canada	6.75	7.31	7.51	6.78	6.28	6.77	5.81	5.77
India	1.97	2.50	4.48	5.14	5.22	5.58	5.78	5.61
Italy	2.28	3.20	3.80	5.31	4.77	5.37	4.96	4.79
Spain	2.03	3.46	4.13	4.78	4.43	4.84	4.97	4.59
France	4.20	5.80	5.36	5.26	5.17	5.32	4.55	4.45
…	…	…	…	…	…	…	…	…
Japan	3.15	3.67	3.36	3.83	3.48	3.53	3.20	2.47
Hong Kong	0.75	0.81	1.17	2.07	1.97	2.13	2.01	2.31
South Africa	1.39	1.87	2.08	2.26	2.03	2.49	2.35	1.89
Denmark	1.21	1.70	1.84	2.45	2.22	2.34	2.04	1.87
Pakistan	0.14	0.25	0.44	1.34	1.22	1.55	1.74	1.82
Position of a country in the global ranking by number of citations received on publications in "Circular Economy" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	14	8	3	2	2	2	2	2
UK	2	2	2	3	3	3	3	3
Australia	4	5	6	4	4	4	4	4
Germany	5	3	4	5	5	5	5	5
Canada	3	4	5	6	6	6	6	6
India	13	14	9	9	7	7	7	7
Italy	11	12	12	7	9	8	9	8
Spain	12	11	10	10	10	10	8	9
France	6	6	7	8	8	9	10	10
…	…	…	…	…	…	…	…	…
Japan	8	9	13	14	14	13	15	17
Hong Kong	26	25	25	23	22	21	20	18
South Africa	15	16	17	19	21	18	18	19
Denmark	18	17	19	18	19	19	19	20
Pakistan	43	41	38	31	30	30	26	21
Citation impact of country in "Circular Economy" domain relative to world, points								
USA	2.06	2.05	2.23	2.07	1.90	1.80	1.74	1.43
China	0.73	0.56	0.91	2.08	2.40	2.32	2.30	1.87
UK	1.90	2.44	2.36	2.34	2.09	1.93	1.80	1.55
Australia	2.11	1.77	2.11	2.31	2.13	2.08	2.04	1.88
Germany	1.78	2.16	2.31	2.37	2.02	1.94	1.87	1.56
Canada	2.27	2.47	2.82	2.47	2.10	2.19	1.93	1.70
India	1.34	1.54	1.80	1.27	1.09	1.13	1.15	1.04
Italy	1.36	1.80	2.07	2.18	1.84	1.87	1.76	1.54
Spain	1.52	2.09	2.28	2.30	1.94	1.94	1.98	1.58
France	1.86	2.51	2.33	2.20	1.98	1.97	1.75	1.62
…	…	…	…	…	…	…	…	…
Japan	0.78	1.06	1.40	1.81	1.52	1.50	1.41	1.04
Hong Kong	1.40	1.65	2.79	3.92	3.20	3.37	3.03	2.54
South Africa	1.23	1.49	1.58	1.47	1.14	1.32	1.27	0.94
Denmark	2.01	2.57	2.62	3.00	2.37	2.49	2.25	1.80
Pakistan	0.76	1.16	1.23	2.07	1.76	1.93	1.82	1.69

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph and Crossref database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

When we look at the publication activity in the Education domain, similar to the other domains, South Africa has experienced a jump in 2015 (Table 3.12). The country's share in global scientific output has increased to 2.18%, which is significant. With these figures, the country occupies the 11th position in the world. This high ranking scientific position should be used as a direver for high-tech industrialisation, transition to circular economy, and overall development of socio-ecomic life.

Table 3.12. Key indicators of publication Activity of South Africa and leading countries in "Education" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Number of publication of a country in "Education" domain, thousands units								
World	**102.5**	**186.8**	**352.2**	**519.0**	**491.1**	**451.5**	**436.0**	**288.5**
USA	29.2	46.4	70.3	96.3	93.5	85.9	82.5	64.5
UK	8.8	14.4	23.9	33.3	33.4	33.7	32.6	24.8
China	1.4	10.6	28.8	23.1	17.0	18.2	20.9	17.7
Australia	4.1	8.6	14.7	19.6	19.1	18.9	17.5	13.3
Canada	3.1	5.9	9.9	14.2	14.3	13.8	13.7	10.7
Germany	2.3	4.5	8.5	12.3	12.7	12.5	13.1	9.8
India	0.7	1.5	4.8	12.3	14.2	12.9	12.2	8.3
Spain	1.1	2.4	6.0	10.2	10.8	10.9	10.8	8.0
Italy	1.2	2.6	5.0	8.8	8.8	9.1	9.3	6.9
Brazil	0.8	2.1	5.8	10.1	10.6	9.0	9.5	6.6
South Africa	1.3	2.8	5.4	9.2	9.8	8.9	8.8	6.3
Netherlands	1.5	2.9	5.2	7.4	7.6	7.8	7.9	5.9
France	1.4	2.7	5.2	7.4	7.9	7.5	7.5	5.5
Japan	1.9	3.2	4.5	6.2	6.2	6.2	6.5	4.5
Sweden	1.0	2.0	3.4	5.5	5.0	4.9	4.9	3.7
Share of country in the global number of publications in "Education" domain, %								
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
USA	28.52	24.84	19.95	18.56	19.04	19.04	18.93	22.36
UK	8.57	7.70	6.78	6.42	6.79	7.46	7.49	8.59
China	1.33	5.66	8.18	4.46	3.46	4.03	4.80	6.12
Australia	3.98	4.61	4.17	3.78	3.89	4.18	4.00	4.61
Canada	2.98	3.15	2.82	2.74	2.91	3.05	3.14	3.69
Germany	2.25	2.41	2.40	2.37	2.58	2.76	3.01	3.40
India	0.64	0.80	1.36	2.37	2.89	2.85	2.81	2.87
Spain	1.04	1.31	1.69	1.97	2.20	2.41	2.48	2.76
Italy	1.16	1.39	1.42	1.70	1.80	2.01	2.13	2.40
Brazil	0.81	1.14	1.65	1.95	2.15	1.98	2.18	2.28
South Africa	1.29	1.52	1.55	1.77	1.99	1.97	2.01	2.18
Netherlands	1.46	1.53	1.47	1.42	1.55	1.73	1.82	2.03
France	1.33	1.44	1.49	1.42	1.61	1.67	1.72	1.91
Japan	1.82	1.69	1.28	1.19	1.26	1.36	1.50	1.55
Sweden	0.96	1.06	0.97	1.05	1.03	1.08	1.13	1.29
Position of a country in the global ranking by number of publications in "Education" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
UK	2	2	3	2	2	2	2	2
China	8	3	2	3	4	4	3	3
Australia	3	4	4	4	3	3	4	4
Canada	4	5	5	5	5	5	5	5
Germany	5	6	6	6	7	7	6	6
India	17	17	13	7	6	6	7	7
Spain	12	12	7	8	8	8	8	8
Italy	11	11	12	11	11	9	10	9
Brazil	14	13	8	9	9	10	9	10
South Africa	10	9	9	10	10	11	11	11
Netherlands	7	8	11	13	13	12	12	12
France	9	10	10	12	12	13	13	13
Japan	6	7	14	15	14	14	14	14
Sweden	13	14	16	17	19	18	17	15

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

Table 3.13 shows the key citation indicators in South Africa. The country's sharein global citations has been high since 2015. South Africa occupies the 14th position globally in terms of citations received. The global impact of the country has slightly increased in the past 20 years.

Table 3.13. Key citation indicators of South Africa and leading countries on "Education" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Share of a country in the global number of citation received on publications in "Education" domain, %								
USA	57.70	52.12	46.61	45.32	44.05	42.37	41.18	41.43
UK	13.58	14.85	14.77	16.63	16.76	18.39	16.79	15.88
China	0.83	2.03	4.67	8.25	9.29	11.56	13.49	12.28
Australia	8.22	6.73	8.13	9.39	9.94	9.61	8.85	7.91
Canada	6.68	6.71	7.50	7.74	8.15	8.73	7.11	6.53
Germany	3.95	5.30	5.98	7.16	7.29	8.76	7.57	6.24
Italy	1.75	2.32	2.95	4.68	4.78	5.44	5.16	4.57
Spain	1.38	1.93	2.82	4.28	4.39	5.10	4.95	4.22
Netherlands	2.20	3.73	4.59	5.06	4.95	5.69	5.15	3.96
France	2.06	2.79	3.21	4.07	4.94	5.11	4.41	3.81
India	0.76	0.88	2.01	3.18	3.48	4.10	3.86	3.31
Brazil	0.79	1.07	1.55	2.16	2.28	2.60	2.19	3.04
Switzerland	1.52	2.49	2.91	4.20	3.48	3.61	3.76	2.93
South Africa	1.29	2.40	2.67	3.14	3.02	3.24	2.90	2.25
Sweden	1.87	2.07	2.09	3.07	2.94	3.58	3.12	2.25
Position of a country in the global ranking by number of citations received on publications in "Education" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
UK	2	2	2	2	2	2	2	2
China	18	12	6	4	4	3	3	3
Australia	3	3	3	3	3	4	4	4
Canada	4	4	4	5	5	6	6	5
Germany	5	5	5	6	6	5	5	6
Italy	9	10	9	8	9	8	7	7
Spain	11	13	11	9	10	10	9	8
Netherlands	6	6	7	7	7	7	8	9
France	7	7	8	11	8	9	10	10
India	23	24	14	12	11	11	11	11
Brazil	20	22	19	19	18	18	18	12
Switzerland	10	8	10	10	12	12	12	13
South Africa	13	9	12	13	13	14	15	14
Sweden	8	11	13	14	14	13	13	15
Citation impact of country in "Education" domain relative to world, points								
World	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
USA	2.02	2.10	2.34	2.44	2.31	2.23	2.18	1.85
UK	1.58	1.93	2.18	2.59	2.47	2.46	2.24	1.85
China	0.63	0.36	0.57	1.85	2.69	2.87	2.81	2.01
Australia	2.06	1.46	1.95	2.49	2.56	2.30	2.21	1.72
Canada	2.25	2.13	2.66	2.83	2.80	2.86	2.26	1.77
Germany	1.76	2.20	2.49	3.02	2.83	3.17	2.52	1.84
Italy	1.51	1.67	2.08	2.76	2.65	2.71	2.43	1.90
Spain	1.33	1.48	1.67	2.17	2.00	2.12	1.99	1.53
Netherlands	1.51	2.45	3.12	3.56	3.20	3.29	2.83	1.94
France	1.55	1.95	2.15	2.86	3.08	3.06	2.56	1.99
India	1.18	1.10	1.48	1.34	1.21	1.44	1.37	1.15
Brazil	0.97	0.94	0.94	1.11	1.06	1.31	1.01	1.33
Switzerland	1.94	3.09	3.28	4.85	3.84	3.53	3.60	2.45
South Africa	1.00	1.58	1.73	1.77	1.52	1.64	1.44	1.03
Sweden	1.96	1.95	2.16	2.91	2.86	3.33	2.76	1.74

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph and Crossref database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

In the domain of the High-tech industry, South Africa's scientific output has continuously increased. A slight decrease in 2019 may be because of the incomplete publications in the Scopus database. South Africa's share in as percentage of global publications has continuously increased and reached to 1.65% in 2019.

Table 3.14. Key indicators of publication Activity of South Africa and leading countries in "High-tech Industry" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019
Number of publication of a country in "High-tech Industry" domain, thousands units								
World	**106.5**	**204.8**	**386.6**	**561.7**	**535.8**	**527.7**	**545.5**	**378.7**

Country	2000	2005	2010	2015	2016	2017	2018	2019
USA	26.6	45.4	69.3	97.3	97.6	99.2	103.6	80.6
China	2.8	18.1	50.2	50.5	46.5	53.8	65.0	55.6
UK	8.4	13.1	21.1	31.9	33.2	34.7	35.2	27.7
India	1.0	2.4	8.4	22.3	25.9	26.0	27.0	19.7
Germany	3.9	7.1	13.2	19.5	20.6	21.3	22.4	16.7
Australia	3.2	7.0	11.5	16.5	16.3	17.1	17.4	13.7
Canada	2.9	5.8	9.3	14.2	14.9	15.1	15.8	12.5
Italy	1.9	4.1	7.7	14.2	14.4	15.8	15.9	12.2
Spain	1.2	3.3	7.0	11.3	11.7	12.3	12.8	10.0
Korea Rep.	1.2	3.8	7.9	12.8	11.8	11.0	11.5	9.9
…	…	…	…	…	…	…	…	…
Netherlands	1.9	3.4	5.8	8.4	8.6	9.0	9.4	7.1
Iran	0.1	0.6	2.8	6.4	6.7	6.5	6.8	6.5
South Africa	1.2	2.4	4.7	7.9	8.4	8.3	8.0	6.2
Switzerland	1.3	2.3	4.3	6.5	6.5	6.7	6.7	5.2
Sweden	1.2	2.5	4.4	6.7	6.5	6.4	6.9	5.1
Share of country in the global number of publications in "High-tech Industry" domain, %								
World	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
USA	25.03	22.18	17.92	17.32	18.22	18.79	18.99	21.28
China	2.60	8.84	12.99	8.98	8.68	10.20	11.92	14.68
UK	7.85	6.39	5.45	5.69	6.20	6.58	6.46	7.31
India	0.91	1.16	2.18	3.97	4.83	4.93	4.95	5.20
Germany	3.67	3.47	3.40	3.47	3.84	4.03	4.11	4.40
Australia	2.98	3.41	2.98	2.93	3.05	3.24	3.20	3.62
Canada	2.69	2.84	2.42	2.53	2.78	2.87	2.91	3.31
Italy	1.82	1.99	1.98	2.53	2.69	2.99	2.91	3.23
Spain	1.16	1.60	1.81	2.00	2.19	2.32	2.35	2.65
Korea Rep.	1.15	1.86	2.05	2.27	2.21	2.09	2.11	2.62
…	…	…	…	…	…	…	…	…
Netherlands	1.74	1.67	1.50	1.50	1.61	1.71	1.73	1.89
Iran	0.08	0.30	0.73	1.14	1.24	1.24	1.24	1.71
South Africa	1.12	1.18	1.21	1.40	1.58	1.57	1.47	1.65
Switzerland	1.20	1.14	1.11	1.15	1.22	1.27	1.22	1.37
Sweden	1.10	1.20	1.13	1.20	1.21	1.22	1.26	1.34
Position of a country in the global ranking by number of publications in "High-tech Industry" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	7	2	2	2	2	2	2	2
UK	2	3	3	3	3	3	3	3
India	16	15	8	4	4	4	4	4
Germany	3	4	4	5	5	5	5	5
Australia	5	5	5	6	6	6	6	6
Canada	6	7	6	7	7	8	8	7
Italy	9	9	11	7	8	7	7	8
Spain	12	12	12	12	12	11	10	9
Korea Rep.	13	10	10	9	10	12	12	10
…	…	…	…	…	…	…	…	…
Netherlands	10	11	13	14	14	14	14	14
Iran	44	35	20	19	17	18	20	15
South Africa	14	14	15	15	15	15	15	16
Switzerland	11	16	17	18	18	17	21	17
Sweden	15	13	16	17	19	19	17	18

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

Table 3.15 shows the key citation indications in the High-tech industry domain. According to the table South Africa's share in global citation figures has remained stable. In terms of citation based global rankings South Africa has dropped from the 16th position in 2000 to 21st in 2019. In parallel, the impact of went down. In order to meet targets regarding High-tech industrialisation, the country needs to advance its scientific capacity.

Table 3.15. Key citation indicators of South Africa and leading countries on "High-tech Industry" domain in Microsoft Academic Graph database

Country	2000	2005	2010	2015	2016	2017	2018	2019

Share of a country in the global number of citation received on publications in "High-tech Industry" domain, %								
USA	51.50	47.10	43.94	41.20	40.05	37.18	35.95	33.40
China	1.89	5.15	10.92	18.96	20.61	22.17	25.47	26.57
UK	14.16	14.23	12.60	12.65	11.94	12.79	11.76	11.70
Australia	5.86	4.85	5.93	6.83	6.25	6.58	6.77	7.19
Germany	5.92	6.61	8.20	7.83	7.29	7.53	7.01	6.41
Canada	6.06	5.69	6.66	6.14	6.11	6.40	5.61	6.06
India	1.25	1.51	3.29	4.38	4.48	4.76	5.31	5.19
Italy	2.37	3.30	3.86	5.06	4.56	4.91	4.70	4.92
Spain	1.55	2.79	3.40	3.99	3.76	3.92	4.16	4.40
France	3.17	4.45	4.96	4.25	4.20	4.29	3.90	4.35
…	…	…	…	…	…	…	…	…
Singapore	0.81	1.02	1.64	2.45	2.49	2.36	2.32	2.24
Pakistan	0.12	0.21	0.40	1.05	0.99	1.26	1.24	1.65
South Africa	1.26	1.75	1.92	1.86	1.49	1.72	1.64	1.45
Malaysia	0.19	0.25	1.16	1.67	1.57	1.47	1.31	1.41
Belgium	1.45	1.85	2.04	1.91	1.68	1.57	1.71	1.41
Position of a country in the global ranking by number of citations received on publications in "High-tech Industry" domain (among top-50 countries by number of publications for 2000-2019)								
USA	1	1	1	1	1	1	1	1
China	11	5	3	2	2	2	2	2
UK	2	2	2	3	3	3	3	3
Australia	5	6	6	5	5	5	5	4
Germany	4	3	4	4	4	4	4	5
Canada	3	4	5	6	6	6	6	6
India	17	17	12	9	8	8	7	7
Italy	10	10	10	7	7	7	8	8
Spain	13	12	11	12	10	11	9	9
France	7	7	7	10	9	9	10	10
…	…	…	…	…	…	…	…	…
Singapore	22	24	19	16	15	17	17	19
Pakistan	40	39	36	32	31	27	26	20
South Africa	16	16	17	20	23	20	21	21
Malaysia	36	35	25	23	22	24	24	22
Belgium	15	15	16	19	20	22	20	23
Citation impact of country in "High-tech Industry" domain relative to world, points								
USA	2.06	2.12	2.45	2.38	2.20	1.98	1.89	1.57
China	0.73	0.58	0.84	2.11	2.37	2.17	2.14	1.81
UK	1.80	2.22	2.31	2.22	1.93	1.94	1.82	1.60
Australia	1.96	1.42	1.99	2.33	2.05	2.03	2.12	1.98
Germany	1.61	1.91	2.41	2.26	1.90	1.87	1.71	1.46
Canada	2.26	2.00	2.76	2.42	2.20	2.23	1.93	1.83
India	1.37	1.31	1.51	1.10	0.93	0.97	1.07	1.00
Italy	1.30	1.66	1.95	2.00	1.69	1.64	1.62	1.52
Spain	1.34	1.74	1.88	1.99	1.71	1.69	1.77	1.66
France	1.59	2.15	2.34	1.91	1.71	1.67	1.56	1.66
…	…	…	…	…	…	…	…	…
Singapore	1.52	1.65	3.22	4.05	3.62	3.05	2.88	2.29
Pakistan	0.86	0.96	1.15	1.90	1.61	1.68	1.37	1.60
South Africa	1.12	1.49	1.59	1.33	0.94	1.10	1.11	0.88
Malaysia	0.73	0.63	1.24	1.21	1.18	0.99	0.91	1.17
Belgium	1.87	2.29	2.63	2.39	2.03	1.93	2.13	1.59

Source: Authors' calculations from data derived by iFORA from Microsoft Academic Graph and Crossref database. All types of publications are included in the analysis. Data is current as of December 2019. Data for 2018 and 2019 is incomplete.

4. EXPERT-BASED SPECIFICATIONS OF PRIORITIES

The above-presented results based on application of quantitative methods of statistical, semantic and scientometric analyses have been complemented with activities based on qualitative methods, including joint workshops and expert consultations. In course of two workshops, a number of highly qualified South African experts had a chance to discuss the preliminary results of quantitative studies with the project team. They shared their opinions to better address and focus analysis to local context and problems the National Innovation System of South Africa faces with, thus provided specific, measurable, actionable, realistic, relevant and time-bound targets for scientifically grounded socio-economic policy recommendations addressing the challenges of South Africa.

4.1. Identifying and clarifying the priority areas (interpretation and priority setting)

At the first expert workshop held on 22 January 2021, the preliminary report containing results of statistical analysis, semantic analysis of big data and bibliometric analysis was discussed by more than 30 high-level South African experts. The report had been sent to experts in advance and its key results were presented at the workshop followed by discussions after presenting each of four potential priority domains proposed for analysis within the project:

- Circular economy/climate change;
- Health innovation;
- Education for the future and the future of society; and
- High-tech industrialisation

The initial semantic analysis presented in the preliminary report proposed 28 clusters to be addressed by experts (see Table 4.1). Each of these clusters was formulated as a set of three terms automatically identified by semantic analysis as most frequently met in relevant sources of data. For each cluster information on its relevance to Experts, while discussing each priority domain and relevant clusters, proposed a number of important issues to be addressed by further analysis.

Table 4.1. Initial set of clusters identified by means of semantic analysis

#	**Priority domain / Initial cluster name**
1	**Circular economy/climate change**
1.1	Climate change, global warming, fossil fuel
1.2	Electric vehicle, battery life, energy storage
1.3	Food chain, natural world, marine life
1.4	Heavy rain, 3D printing, solar system
1.5	Natural resource, food industry, food safety

1.6	Potential, AI, economic growth
1.7	Renewable energy, solar panel, power plant
2	**Health innovation**
2.1	AI, machine learning, mobile applications
2.2	Clinical trial, high risk, increase risk
2.3	Health care, patient care, health system
2.4	Immune system, immune response, zika virus
2.5	Sexual violence, birth control, sexual activity
2.6	Weight loss, physical activity, healthy lifestyle
2.7	Young people, global warming, rural area
3	**Education for the future and the future of society**
3.1	Campus, high school, college student
3.2	Culture, background, big challenge
3.3	Education, high education, school district
3.4	Minimum wage, unemployment rate, job creation
3.5	Mobile device, AI, machine learning
3.6	Top talent, technical support, training program
3.7	Young people, young woman, video game
4	**High-tech industrialisation**
4.1	Blockchain technology, digital currency, bitcoin price
4.2	Cyber attack, cyber security, identity theft
4.3	Financial service, national security, decision making
4.4	Mobile device, AI, machine learning
4.5	Mobile payment, financial transition, banking industry
4.6	Personal information, sensitive information, facial recognition
4.7	Renewable energy, electric vehicle, energy efficiency

During the workshop experts provided a number of valuable ideas related to all potential priority domains. Among fundamental issues it was underlined that "… at the basis of the Decadal Plan priorities is an investment decision to be made by a severely fiscally strained state. Therefore, detailed techno-economic analyses should follow these discussions. And pivotal to this would be an understanding of our R&D capabilities as well as the absorptive capacity of a very unequal society". It means that practical decision making – while taking account of the identified priorities – should look well beyond R&D as a driver for innovation. Experts underlined importance of engaging systemic enablers and a need in additional information on necessary specific skills, infrastructure, required investment, possible sources of such investment etc. It will require additional discussions with relevant officials and industry representatives pursuing a cooperative approach with industry and civil society.

Other general issues included looking for a balance is needed between disruptive and incremental innovations; avoiding excessive use of "fashionable" hype terms like 4th Industrial Revolution. Experts also addressed a number of issues related to particular domains like productive capacities of Health industry as consumers producer of health technologies and vaccines; a need in a longer-term strategy for transition to Circular economy and its links to sustainable livelihoods; a fundamental transformation of the economy through radical innovation and the

democratisation of the society; underestimated importance of cybersecurity for business; proper sanitation as a key issue for education, etc.

Altogether, experts focused on a number of areas that could be considered as priorities for South Africa taking account of its local context. A list of these areas is presented in Table 4 .2

Table 4.2. The set of clusters revised on the basis of expert discussions

#	**Priority domain / Revised cluster name**
1	**Circular economy/climate change**
1.1	Clean energy solutions
1.2	Sustainable and modernized agriculture
1.3	Zero waste manufacturing
1.4	Economic growth
1.5	Efficiency in resource utilization
2	**Health innovation**
2.1	Reducing the burden of HIV and TB
2.2	Application of e-health service delivery systems
2.3	Reducing levels of maternal death
2.4	Improving access to quality healthcare services
3	**Education for the future and the future of society**
3.1	Mass roll-out of low-cost, low-maintenance Wi-Fi (broadband), connectivity to rural areas to enable remote teaching and learning
3.2	ICT application in education
3.3	Development of industry relevant curriculum (digitization, programming, entrepreneurship and robotics)
3.4	Development of globally competitive workforce
4	**High-tech industrialisation**
4.1	Manufacturing extension services, focusing on digitalization and cyber security support for manufacturing
4.2	Job creation
4.3	Productivity increase in manufacturing
4.4	Export growth
4.5	Increasing GDP contribution
4.6	New high-tech SMMEs development

The areas proposed by experts were rather uneven, some of them – such as Economic growth, Export growth and Job creation – just repeated indicators of socioeconomic impact of the selected STI priorities analysed with statistical and semantic method (see above *Background and objectives* part of the report). Therefore, further analysis was needed to identify priority areas and estimate their potential socio-economic impact for South Africa.

4.2. Strategizing and policy recommendations

Strategizing and policy recommendation were the subject of the second workshop, which took place on 29 January 2021. For each of earlier proposed priority areas by experts (Table 4.2), the following issues were discussed: year of realization; key issues for S&T policy; other

government initiatives; actions to be made. The ideas proposed by experts at the first workshop were systemized and presented across four priority domains (see Table 4.3).

Table 4.3. Outcomes of the first workshop presented at the second workshop.

Domain	Experts' proposals
Health innovation	
Year of realization	Short to mid term (3-5 years)
Key issues for S&T policy	Development of RDI capabilities in the areas of New treatment and prevention; technologies; Precision Medicine; Digital Health and use of indigenous knowledge; Developing capabilities in vaccine production; 1) Formation of consortia for development of technology platforms for vaccine discovery, development and production 2) SA should use ML and AI in managing prevalent communicable diseases such as TB, HIV and COVID-19. 3) Nurture multidisciplinary R&D and piloting for health technologies such as biosensors & other diagnostic devices, respirators, etc. Build sufficient local capacity for health technology assessment (including universities having relevant courses in their curriculum) 4) Strengthen R&D programmes aimed at technological know-how and piloting of advanced pharmaceutical ingredients (API) through PPP. Technology Platforms for API research and manufacturing should be strengthened for a huge and accelerated impact 5) Support of R&D and innovation for reduction of non-communicable diseases resulting from poor diet, smoking and alcohol. R&D efforts should be intensified for solutions leading to improved diet and minimisation of the harmful effects of tobacco and alcohol. Joint public-private R&D partnerships (research chairs or centres of excellence) are ideal for uptake of solutions developed.
Other government initiatives	Department of Health of health sector masterplan and the National Treasury (NT) on funding
Actions	1) National Department of Health Should take lead on a broader health policy issues; 2) Dep.t of S&I should lead in supporting health related innovation RDI
High-tech industrialisation	
Year of realization	Short to mid term (3-5 years)
Key issues for S&T policy	1)Strengthning RDI capabilities in the areas of biotechnlogy, advanced manufacuring, space science and ICT; 2 Improved funding for RDI in these areas;
Other government initiatives	The DTIC on manufacuring support programme; Chemical, sugar, manufacturing and automatic sector masterplan; DSBD on SMMEs support and the National Treasury (NT) on funding
Actions	1) Department of Trade, Industry and Competition (the DTIC) to champion access to market opportunities and drive export growth for high-tech products; 2) Department of Small Business and Development (DSBD) to lead in the area of high-tech SMMEs development and high-tech localisation and 3) The DSI to lead on the implementation of RDI interventions
Circular Economy and Climate change	
Year of realization	Short to mid term (3-5 years)
Key issues for S&T policy	1)greenhouse gas emissions; 2) Transition to low -carbon economy; 3) Impact of climate change in food supply and security
Other government initiatives	Department of Environment, Forestry and Fisheries on zero waste to landfill; climate change mitigation and adaptation; National response to international policy instruments; the National Treasury (NT) on funding
Actions	1) Department of Environment forestry and Fisheries to lead on the broader policy issues relating to circular economy and climate change; 2) DSI to lead on the implementation of RDI interventions
Education and future of society	
Year of realization	Short to mid term (3-5 years)
Key issues for S&T policy	High level of literacy amongst kids; Access to quality education; High rate of unemployment among graduates
Other government initiatives	Department of Basic Education on early childhood development; Department of higher education of relevant skills of the future development; and the National Treasury (NT) on funding
Actions	1) Both the Dep.t of Basic and Higher Education to lead on the policy issues regarding provision and access to quality of education; DSI to lead in strengthening RDI capabilities in the higher education sector

Expert discussion was concentrated around clarification of concrete priorities and potential policy measures to be implemented in each priority domain. A number of proposals were given during the workshop, including the following:

- Role of innovative technology in reproductive health
- Emphasising strategic expenditure in health as an investment in the country's productive capacity and realising people's potential, job creation, etc.
- Addressing equity issue in the health system, given that it is highly unequal in distribution of resources and outcomes.
- Using a systemic approach addressing design of such systems as: 1) energy, 2) industry, 3) transport, 4) food and 5) settlements
- Add to priorities hydrogen and CCS technologies; dietary changes; alternative building materials and low carbon steel and cement
- Providing Internet access with respect to settlement densification and intersections
- Modal shifts in transport (rail, heavy transport and consumer transport; leisure transport: air and cruise shipping and its links to tourism)
- Check out the work of We Mean Business and the World Business Council for sustainable development
- Industrial Internet of things (IIoT) should be considered under number IR4.0
- Video games useful in stimulating cognitive abilities

More concrete proposals were sent by experts as a follow-up of the workshop. Based on experts' judgements and their additional proposals, the above-presented set of clusters was reformulated (see Table 4.4).

Table 4.4. The set of clusters revised on the basis of expert discussions

#	**Priority domain / Revised cluster name**
1	**Circular economy/climate change**
1.1	Climate change
1.2	Energy storage and transport
1.3	Ecosystem
1.4	Water security
1.5	Sustainable agriculture & food
1.6	Circular economy
1.7	Clean and renewable energy
2	**Health innovation**
2.1	e-Health
2.2	Preventive medicine
2.3	Unified healthcare system
2.4	Immune system and vaccination
2.5	Reproductive health
2.6	Healthy lifestyle

2.7	External factors
3	**Education for the future and the future of society**
3.1	Higher education
3.2	Socio-economic development
3.3	Primary education
3.4	Employment & job creation
3.5	IT for education
3.6	Career development
3.7	Personal skills development
4	**High-tech industrialisation**
4.1	Blockchain and digital currency
4.2	Cyber security
4.3	Industry 4.0
4.4	Technology adoption & industrial upgrade
4.5	e-Finance
4.6	Personal information security
4.7	Renewable energy

The results of the semantic analysis for these clusters are presented above in part 2 of the report.

Two additional clusters were identified: “Waste management” (“Circular economy/climate change” domain) and “Training of trainers” (“Education for the future and the future of society” domain). For each of them, a set of keywords for semantic analysis was developed based on results of the expert discussion and further semantic analysis of relevant big data was provided on the basis of the iFORA system.

The results of semantic analysis for these two clusters are shown below in Figure 4.1 and Figure 4.2.

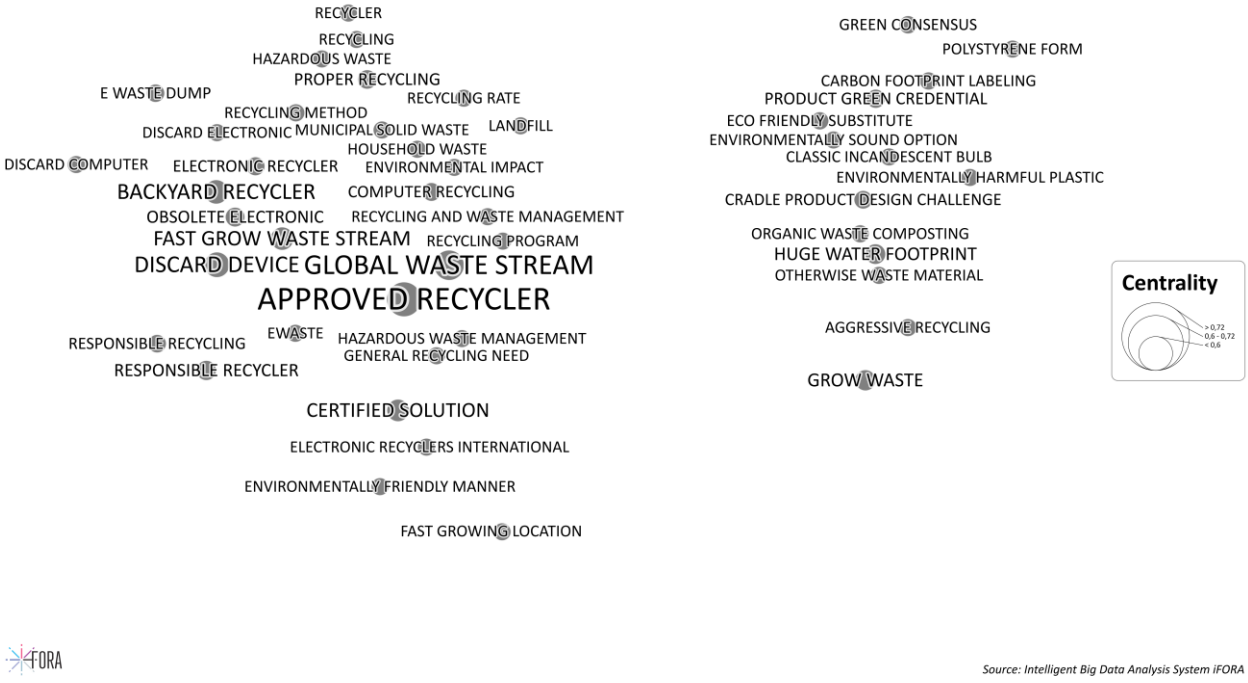

Figure 4.1. Circular economy/climate change. Cluster map. Waste Management

The cluster map shows that topics with the greatest centrality on Waste Management are:

- APPROVED RECYCLER
- GLOBAL WASTE STREAM
- DISCARD DEVICE
- BACKYARD RECYCLER
- FAST GROW WASTE STREAM
- GROW WASTE
- HUGE WATER FOOTPRINT
- RESPONSIBLE RECYCLER
- OBSOLETE ELECTRONIC
- PROPER RECYCLING

Figure 4.2. Education for the future and the future of society. Cluster map. Training for Trainers

The cluster map shows that topics with the greatest centrality on Training of trainers are:

- EXTRA LEARNING TIME
- ACADEMIC AND EXTRA CURRICULAR ACTIVITY
- EXTENSIVE PROFESSIONAL DEVELOPMENT
- EXPERT LEARNER
- ASPIRE EDUCATOR
- COURSE OUTCOME
- CLASSROOM EFFECTIVENESS
- CHILD ACADEMIC DEVELOPMENT
- AVID SCHOOL
- ART LEARNING

In-depth analysis of the two additional clusters is presented in Figure 4.3 and Figure 4.4 below.

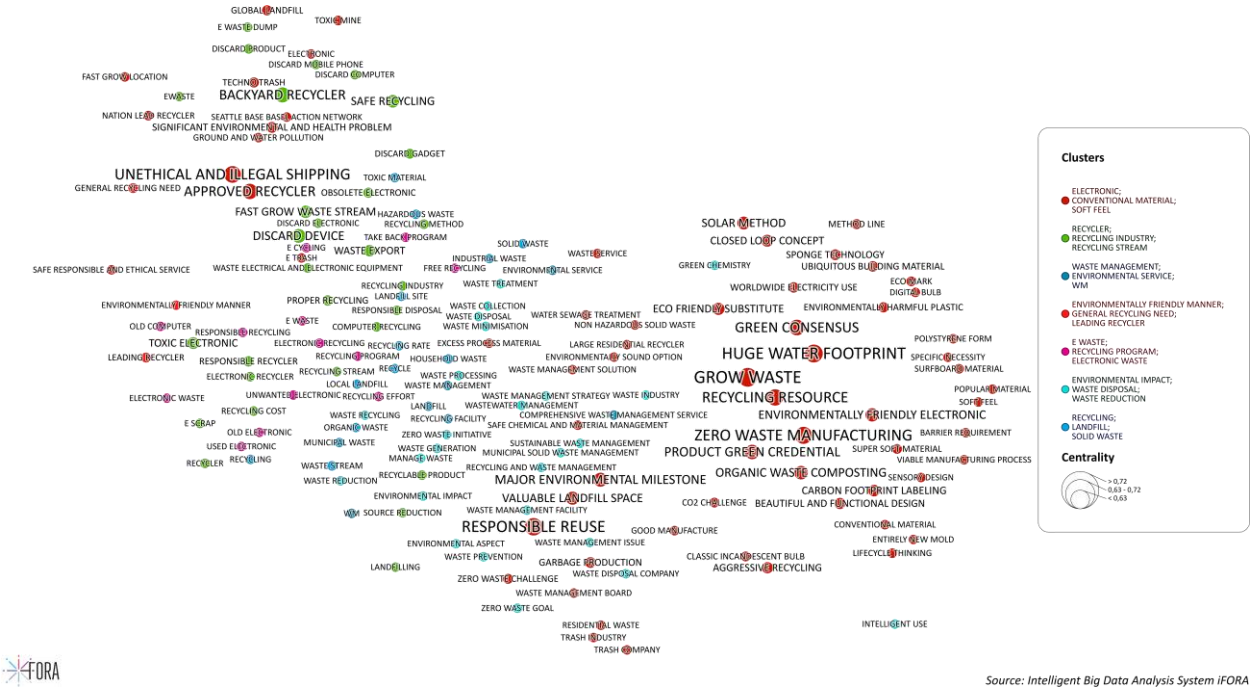

Figure 4.3. Waste Management. Semantic map

The semantic map shows that topics with the greatest centrality on Waste Management are:

- GROW WASTE
- HUGE WATER FOOTPRINT
- RESPONSIBLE REUSE
- ZERO WASTE MANUFACTURING
- UNETHICAL AND ILLEGAL SHIPPING
- RECYCLING RESOURCE
- GREEN CONSENSUS
- APPROVED RECYCLER
- BACKYARD RECYCLER
- PRODUCT GREEN CREDENTIAL

The points on the map are combined into one group, which shows thematic consistency of Waste Management and a high level of interconnection of the key topics of the direction with each other.

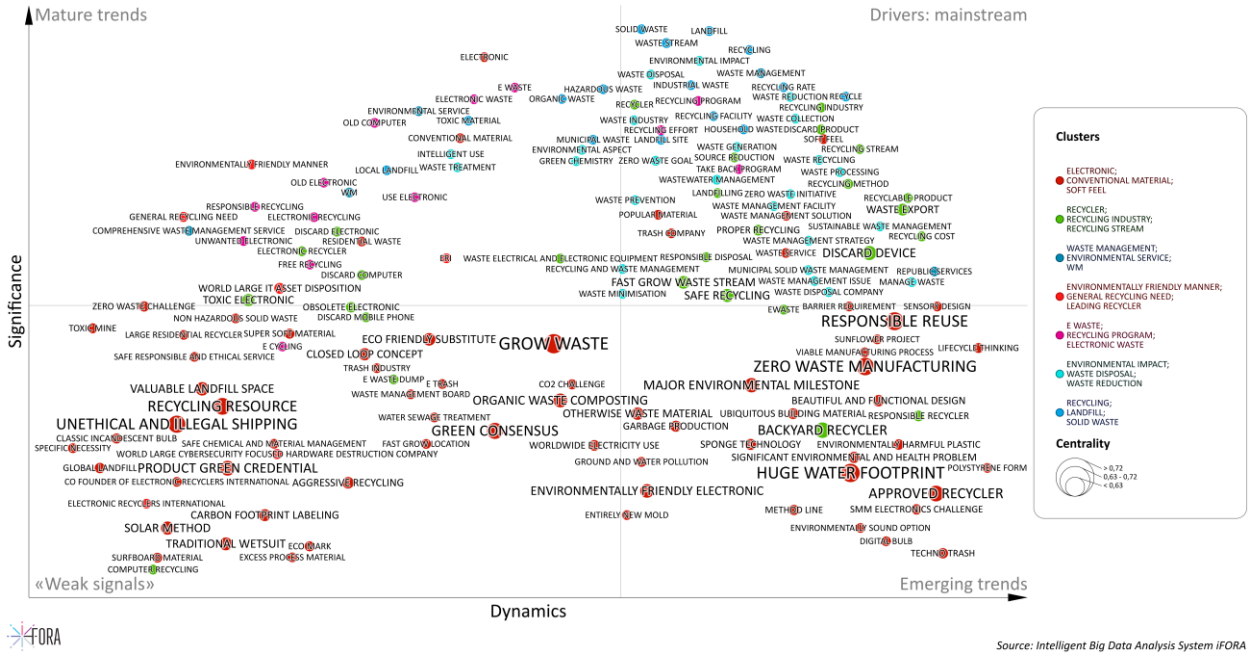

Figure 4.4. Waste Management. Trend map

The trend map shows that topics with the greatest centrality among drivers (mainstream) are:

- DISCARD DEVICE
- SAFE RECYCLING
- FAST GROW WASTE STREAM

Topics with the greatest centrality among mature trends are:

- TOXIC ELECTRONIC
- WORLD LARGE IT ASSET DISPOSITION
- GENERAL RECYCLING NEED

Topics with the greatest centrality among emerging trends are:

- HUGE WATER FOOTPRINT
- RESPONSIBLE REUSE
- ZERO WASTE MANUFACTURING

Topics with the greatest centrality among "weak signals" are:

- GROW WASTE

– UNETHICAL AND ILLEGAL SHIPPING
– RECYCLING RESOURCE

The most central topics are located at the bottom of the trend map, which indicates that the waste management is currently at a stage of development and has not yet reached maturity and stability.

Figure 4.5 presents the semantic map for the Training of Trainers domain

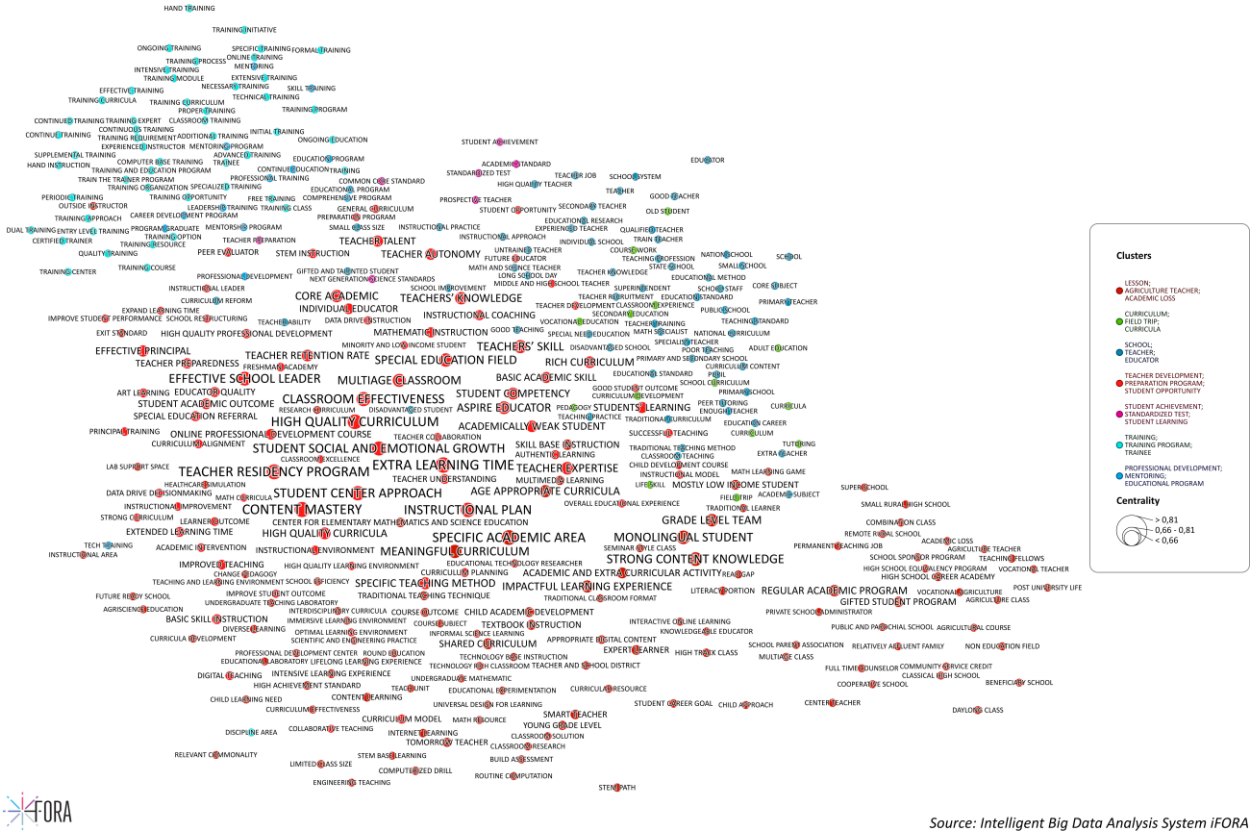

Figure 4.5. Training of trainers. Semantic map

The semantic map shows that topics with the greatest centrality on Training of trainers are:

– EXTRA LEARNING TIME
– CONTENT MASTERY
– TEACHER RESIDENCY PROGRAM
– HIGH QUALITY CURRICULUM
– INSTRUCTIONAL PLAN
– STUDENT CENTER APPROACH
– CLASSROOM EFFECTIVENESS

– STUDENT SOCIAL AND EMOTIONAL GROWTH
– EFFECTIVE SCHOOL LEADER
– SPECIAL EDUCATION FIELD

The points on the map are combined into one group, which shows thematic consistency of Training of trainers and a high level of interconnection of the key topics of the direction with each other.

Figure 4.6 presents the trend map for the Training of Trainers domain

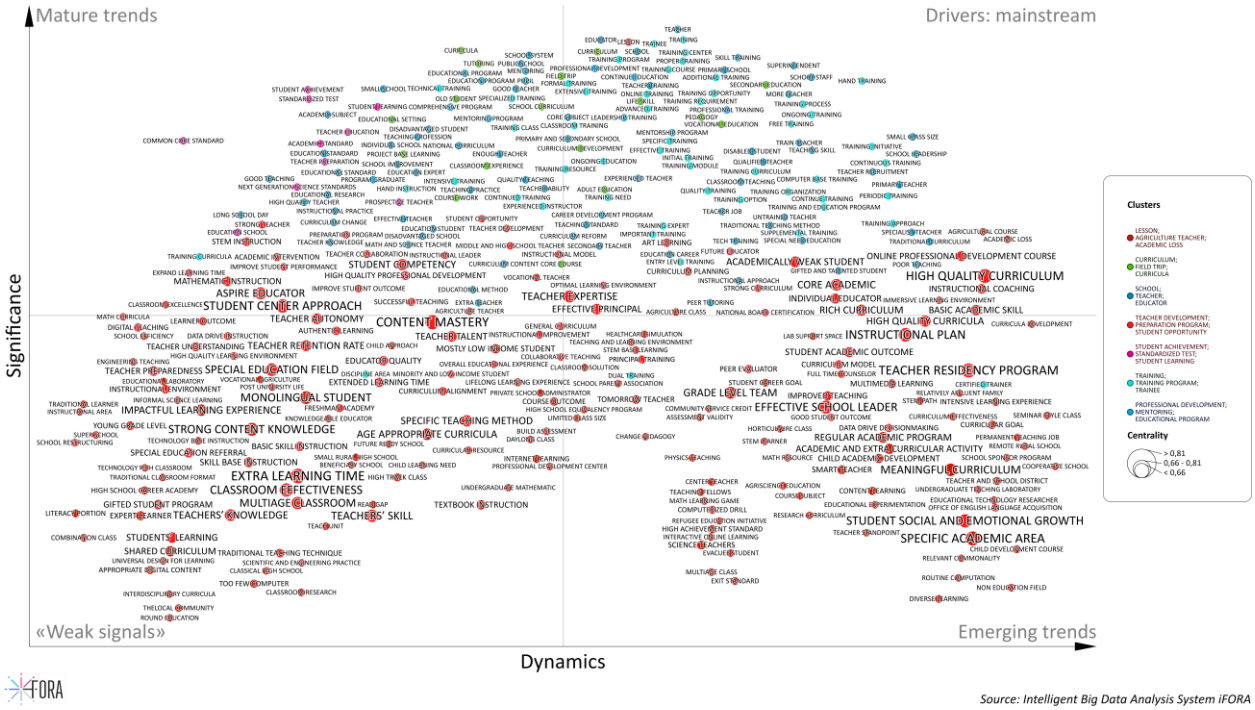

Figure 4.6. Training of trainers. Trend map

The trend map shows that topics with the greatest centrality among drivers (mainstream) are:

– HIGH QUALITY CURRICULUM
– TEACHER EXPERTISE
– CORE ACADEMIC

Topics with the greatest centrality among mature trends are:

– STUDENT CENTER APPROACH
– ASPIRE EDUCATOR

– STUDENT COMPETENCY

Topics with the greatest centrality among emerging trends are:

– TEACHER RESIDENCY PROGRAM
– INSTRUCTIONAL PLAN
– STUDENT SOCIAL AND EMOTIONAL GROWTH

Topics with the greatest centrality among "weak signals" are:

– EXTRA LEARNING TIME
– CONTENT MASTERY
– CLASSROOM EFFECTIVENESS

The most central topics are located at the bottom of the trend map, which indicates that the training of trainers is currently at a stage of development and has not yet reached maturity and stability. However, there are several significant terms in the upper part of the trend map, indicating the ongoing process of development of the training of trainers.

4.3. Policy implications

Experts have noted relevance of the methodology used in the study to the task of measuring socio-economic impact of priority areas of science and technology development on South Africa. Nevertheless, many of them underlined a need in further analysis while selecting tools for practical decision making, including distribution of funding allocated for individual programmes and projects.

Among overall issues to be addressed by policy making, experts underlined the following:

- a need to consider particular individual areas at macro-, meso- and micro-level;
- subdivide Circular economy and Climate change into two separate areas;
- inequality in different aspects (access to health services; internet; education, etc.);
- need of systemic approach to policy making;
- seeking for a balance between market- and society-driven priority setting;

- engagement of relevant and most knowledgeable experts for further investigating various topics and developing particular policy tools;
- considering some areas like human capability (e.g. education and skills) as cross-cutting fields that have high impact on all other areas;
- removing as much as possible bureaucratic obstacles.

For each of four priority domains, experts proposed relevant individual issues to be addressed, policy agenda. A compilation of proposals is given below.

Health innovation

Vaccine Discovery and Production – Formation of consortia for development of technology platforms for vaccine discovery, development and production will provide for creation of innovation linkages between academia, industry, government, standards developing bodies & other regulators and civil society for accelerated development of vaccines (should be linked to TIA's Drug Discovery and Development (H3-D) technology platform)

Improved Health Information Systems – Covid-19 pandemic has demonstrated how machine learning and artificial intelligence techniques are useful for screening, predicting, forecasting, contact tracing and drug development. South Africa should make use of ML and AI in managing other prevalent communicable diseases such as TB and HIV. In this respect more research and technology platforms should be created and supported (should be linked to South African National Bioinformatics Institute at the University of the Western Cape (established by the MRC).

Affordable Health Technology – Nurturing multidisciplinary R&D and piloting for health technologies such as biosensors & other diagnostic devices, respirators; building sufficient local capacity for health technology assessment (including universities having relevant courses on their curriculum) should target a principle of local production and import substitution for health technologies. This will require skills, standards, shielding & broadening of application of locally developed health technologies (should be linked to National Ventilator Project and TIA's Technology Development Programme).

Generic Drugs Manufacturing – R&D programmes aimed at technological know-how and piloting of advanced pharmaceutical ingredients (API) through public-private partnership; supporting Technology Platforms for API research and manufacturing should be strengthened for

a huge and accelerated impact. STI policy should envisage a landscape study to understand gaps with regard to local APIs production; provision of competitive funding in partnership with large pharmaceutical companies; shielding and broadening application of South African developed APIs (should be linked to NRF's National Equipment Programme is funding API manufacturing R&D (e.g. Nelson Mandela University); South African Research Chairs Initiative (SARChI Chair in Microfluidic Bio/Chemical Processing); API Technology Innovation Cluster Program (hosted by North West University and managed by TIA); Manufacturing Competitiveness Enhancement Programme (MCEP).

Management of Life Style Diseases – Support of R&D and innovation for reduction of non-communicable diseases resulting from poor diet, smoking and alcohol; intensified R&D efforts for solutions leading to improved diet and minimisation of the harmful effects of tobacco and alcohol; joint public-private R&D partnerships (research chairs or centres of excellence) to uptake solutions developed will require from STI policy supporting public-private partnership with the food, tobacco and alcohol manufacturers in seeking innovative solutions to improve their products in a manner that promote a healthy society (should be linked to DSI-NRF Centre of Excellence in Food Security, Centre of Excellence in Non-Communicable Diseases (African Research Universities Alliance)).

Reducing the burden of HIV/AID and TB; Application of e-health service delivery systems; Improving access to quality health care – will require from STI policy developing RDI capabilities in the areas of New treatment and prevention; technologies; Precision Medicine; Digital Health and use of indigenous knowledge; Developing capabilities in vaccine production. Key action needed in this respect from the National Department of Health Should – to take lead on a broader health policy issues and from the Department of Science and Innovation – take lead in supporting health related innovation RDI (should be linked to Department of Health of health sector masterplan and the National Treasury (NT) on funding).

Circular Economy

Clean energy solution; Sustainable and modernised agriculture; Zero waste manufacturing; Efficiency in resource uitlisation – will require STI to address such issues as greenhouse gas emissions; transition to low-carbon economy; impact of climate change in food supply and security. Actions needed include: from the Department of Environment Forestry and Fisheries to lead on the broader policy issues relating to circular economy and climate change; from DSI to lead on the implementation of RDI interventions (should be linked to Department of

The Department of Environment Forestry and Fisheries on zero waste to landfill; climate change mitigation and adaptation; National response to international policy instruments; the National Treasury (NT) on funding).

Water, waste and electricity, as well as manufacturing, agriculture and agri-processing – will require from DTIC – incentives to go green/circular for industry; from Department of Small Business Development – to encourage SMEs to pursue green business maybe through soft loans or grants; from the Department of Environment, Forestry and Fisheries (DEFF) – to put in place enabling regulation and policy; from DSI – to provide the evidence for policy-makers and decision-makers, as well as innovations to enable the shift; from the Department of Minerals and Energy – to make the Integrated Resource Plan a reality; all of this has to be done with Labour and the Private Sector (should be linked to NDP (chapter 5), Sector Masterplans of DTIC, National Waste Management Strategy (DEFF), National Water and Sanitation Masterplan, SDGs, Partnership for Action on Green Economy (PAGE), Bio-economy Strategy, Waste RDI Roadmap, Water RDI Roadmap, Hydrogen Economy, Integrated Resource Plan).

High tech industrialisation

Driving improvement and productivity in the manufacturing/production sector; economic growth in terms of GDP contribution; new high-tech SMMEs development – should require from STI policy to strengthen RDI capabilities in the areas of biotechnology, advanced manufacturing, space science and ICT and increase funding for RDI in these areas. It will require from the Department of Trade, Industry and Competition (DTIC) to champion access to market opportunities and drive export growth for high-tech products; from the Department of Small Business and Development (DSBD) to lead in the area of high-tech SMMEs development and high-tech localization; and from the DSI to lead on the implementation of RDI interventions (should be linked to the DTIC on manufacturing support programme; Chemical, sugar, manufacturing and automatic sector masterplan; DSBD on SMMEs support and the National Treasury (NT) on funding).

Education of the future

Skill development, ICT application in education, development of industry relevant curriculum (digitisation, programming entrepreneurship and robotics); development of globally competitive workforce – will require from STI policy addressing high level of literacy amongst kids; access to quality education; high rate of unemployment amongst graduates. It will envisage

from the Department of basic and higher education to lead on the policy issues regarding provision and access to high-quality education and from the DSI to lead in strengthening RDI capabilities in the higher education sector (should be linked to the Department of Basic education on early childhood development; to the Department of higher education on relevant skills of the future development; and to the National Treasury (NT) on funding).

Following the formulation of priorities and policy recommendations experts involved in the process identified target dates for their realization in the short, medium and long term with the target year of 2030. The roadmap is presented in Figure 4.7.

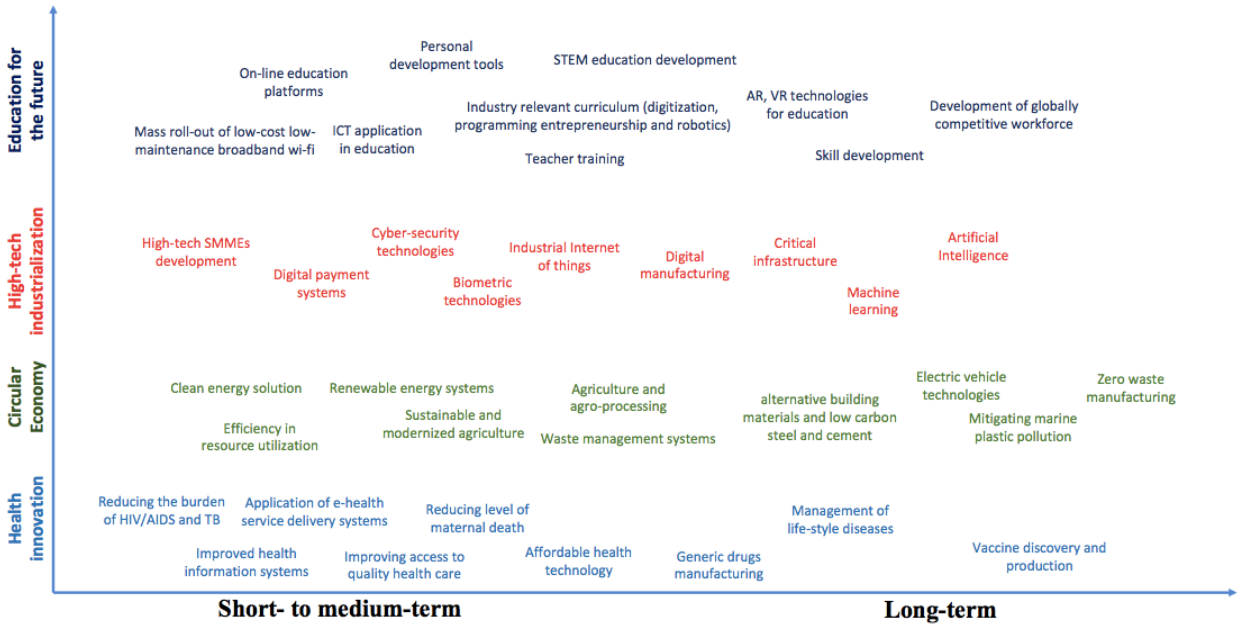

Figure 4.7. Strategic roadmap for the implementation of the policy recommendations

Health innovation is priority for socio-economic development. First and foremost strategies for health innovation is reducing the burden of HIV/AIDS, Tuberculosis (TB) and more recently COVID-19 and other pandemics. Meanwhile, there is a need for overhauling the health system in South Africa. As a first step health information systems should be developed, and e-health service delivery systems should be applied. While improving the health system access to quality healthcare services should be provided with affordable health technologies. Maternal death rates are still high, and these should be reduced in the medium term. Generic drugs should be manufactured coupled with the development of vaccines to make sure that within the next decade populations can be vaccinated against the viruses and can receive necessary drugs by the end of the next decade.

Circular economy is one of the four key priority domains, which was considered with an interlinked domain of climate change. For the transition to the circular economy, first of all clean energy solutions should be developed. The statistical analysis presented earlier showed that the South African energy mix is dominated by the coal, which is a major source of emissions. This mix should be enriched with the implementation of new and renewable sources of energy. Meanwhile efficiency of resource utilization should be provided to reduce resource use, waste and emissions. Steps should be taken to modernize the agriculture sector and agro processing. Meanwhile, the loss of agricultural products should be minimized. A shift to electric transport is needed in the medium term. Alternative building materials should be developed and used such as low carbon steel and cement. Buildings should have necessary insulations for heating, ventilation and air conditioning. The long term goal is to achieve zero waste manufacturing and economy overall.

Considering the High-tech industrialisation, one of the most immediate strategies should be to support the small, medium and micro enterprises with necessary skills and infrastructure to be ready for the next industrial revolution. The digitalization of the economy trend will enable the use of digital currencies. In the short to medium term, an economic system should be developed to adopt these financial technologies. Increasing digitalization will also bring the cybersecurity issues on the agenda in the medium term. Among the industrial applications of digitalization are Industrial Internet of Things (IIoT), digital manufacturing and the implementation of Artificial Intelligence and Machine Leaning technologies. Necessary IT infrastructure should be developed for the development of High-tech industrialisation.

According to the strategic roadmap for education for the future, first of all necessary internet (wifi) connection at a low costs to the populations of the country. In parallel, online education systems should be developed in the nearest term. ICT applications in education should be widened and be made more accessible in time. Curricula should be developed with the requirements of the digitalization and industrialisation trends as well as getting ready for transforming to the circular economy. In the medium term, AI and VR technologies should be deployed. All these strategic steps should lead to the development of a globally competitive workforce by 2030.

*****End of the report*****